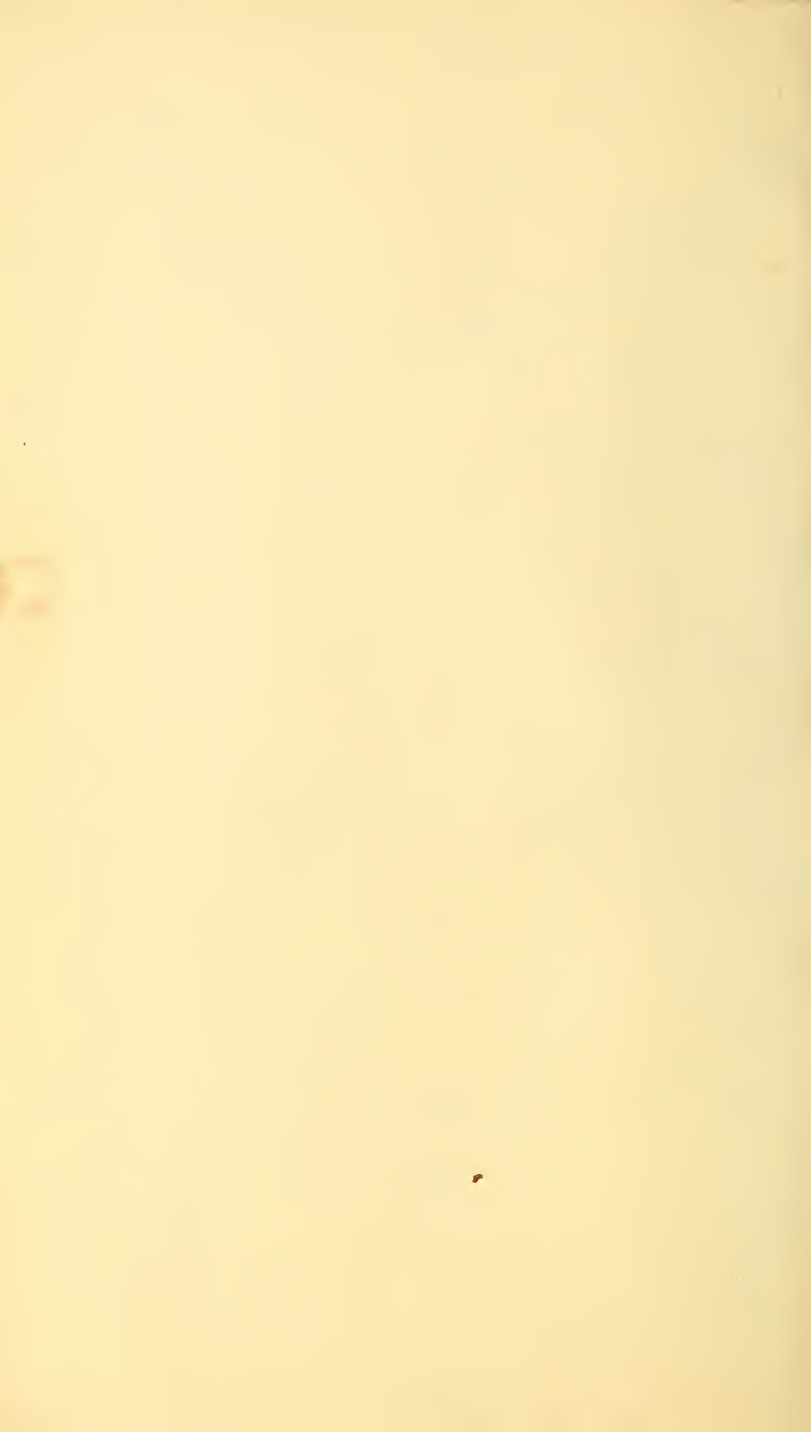




Class _____

Book _____

COPYRIGHT DEPOSIT



FIRST LINES

OF

PHYSIOLOGY,

BEING AN

INTRODUCTION TO THE SCIENCE OF LIFE;

WRITTEN IN POPULAR LANGUAGE.

DESIGNED FOR THE USE OF

COMMON SCHOOLS, ACADEMIES, AND GENERAL READERS.

17
BY REYNELL COATES, M.D.

AUTHOR OF THE FIRST LINES OF NATURAL PHILOSOPHY.

~~~~~  
SIXTH EDITION, REVISED;

WITH AN APPENDIX.  
~~~~~

PHILADELPHIA:

PUBLISHED BY E. H. BUTLER & CO.

1846.

6325
605

Entered according to Act of Congress, in the year 1845, by REYNELL
COATES, M. D., in the Clerk's Office of the District Court for the Eastern
District of Pennsylvania.

6026

J. FAGAN, STEREOTYPER.

TO

A. CRITTENTEN, ESQ.

PRINCIPAL OF THE ALBANY FEMALE ACADEMY.

In just admiration of the talent which conducts to such noble results, the system of instruction under his immediate superintendence—as proved by both the mental culture and the manners of his pupils,

THIS VOLUME

Is Respectfully Dedicated,

BY THE AUTHOR.



PREFACE.

To the earlier editions of this little work, several pages of prefatory matter appeared requisite, in order, partly, to apologize for the introduction of a new candidate for popular favour, in a department of science for which several introductory text-books adapted to the use of schools and unprofessional readers had been previously produced, and, partly, to defend the fitness of Physiology as a branch of elementary education, not only for male children, but for females also.

This necessity is no longer obvious. The rapid succession of reprints which the work has undergone furnishes abundant evidence that it is calculated to supply a deficiency in our means of instruction which is felt and acknowledged by the public; and the author has received, from the publishers, the gratifying assurance that an ample share of the patronage bestowed upon it has been derived from the female schools and academies of the country. He has, therefore, been induced to apply to more useful purpose the chief part of the space formerly devoted to the preface; and now, after very careful revision, the addition of a glossary, and a slight change of title, he no longer fears the charge of immodest presumption in presenting the volume to teachers and general readers who have not as yet examined its contents, as a treatise that has been tested and approved upon authority less questionable than his own.

Many essays designed for similar purposes are ushered into the world with lofty pretensions as to the perfect manner in which the whole field of Physiology is covered within their pages. This pretension is an insult to the understanding of the reader; and in the present undertaking, the author pretends to nothing more than the presentation of such

a general view of the science as he conceives to form a legitimate portion of a strictly elementary education—such a view as will enable the pupil, in after life, to comprehend and to enjoy those profounder works on natural history, hygiene, the fine arts, and even morals, which, without some knowledge of Physiology, are either altogether unintelligible, or vaguely understood.

The practical teacher will find the references to the matter, whether in the Contents, the body of the work, the Questions, or the Glossary, arranged according to the numbers of the paragraphs, and not those of the pages. The Questions have been placed at the end of the text, rather than the bottom of each page, with the express intention of testing more perfectly the comprehension of the pupil; and they are so worded as to render almost impossible the indulgence of the parrot-like propensity to answer in the precise words of the writer. The Glossary follows the Questions, and concludes the volume. It will be found interesting to those who are fond of impressing technicalities upon the memory by the aid of associations connected with their derivation, and will prove a useful guide to the correct pronunciation, as well as the true meaning of the few professional terms which have been unavoidably employed.

The character of the volume being that of a regular treatise, and not a mere compilation, it will be reasonably expected that opinions peculiar to the writer may occasionally appear. This introduction of novelty, so far as the predicates are concerned, has been studiously avoided; but, in the chain of the argument, conclusions strictly logical, and therefore indisputable, have not been suppressed, merely because they have not been embalmed in the dust of the library.

CONTENTS.

CHAPTER I.

ON THE MOTION AND GROWTH OF ANIMATE AND INANIMATE THINGS.

	Paragraph
What constitutes the difference between things which have life and things which have not,	1
Motion is not a proof of life, nor is its absence a proof of the absence of life,	2
Illustrations.—The sleeping dog—the moving watch	2
The stillness of the trees in the absence of wind—the seeming vitality of the eye-stone,	3
Growth is not a proof of life,	4, 5
Illustrations.—The confused ideas of children on this subject—growth of spars in caves—of saltpetre, mould, and mosses in damp places—of iron ore in swamps,	8
Folly of supposing that rocks and stones have an inherent power of growth,	9
Motion and growth are insufficient to distinguish animate from inanimate things,	10
Birth and death are not inherent properties of living things,	11
Inanimate things cannot move by their own energy, but must be moved by other things,	13
Illustrations.—Motion of a falling stone—a vibrating spring—the eye-stone,	13
Living things are moved by other things; but have also other powers of motion,	14
Illustrations.—A man falling by gravity—the limb of a tree vibrating when bent,	14
Inherent power of motion in living things,	15
Illustrations.—Motions of a potatoe sprouting in the dark,	15
Motions of leaves and flowers towards the light—motions observed in <i>Dionæa muscipula</i> ,	16
Motions of animals determined by will,	17
First distinctive property of living things—the power of regulating their own motions,	18
Explanation of the word ORGAN,	19
of the term ORGANIZED BEINGS,	20
of the term ORGANIZATION,	20
Division of matter into organic and inorganic matter,	22

	Paragraph
Explanation of the terms petrification and organic remains— of the term system,	23 24, 25
Difference in the mode of growth of animate and inanimate things,	26
Inanimate things grow by additions to their exterior,	27
Living things grow by additions to their interior,	28, 29
Illustrations.—The formation of sap and blood,	30
Living things construct their own partielles,	31
Organized beings possess the power of moving their own fluids, Apparent growth of inanimate things by internal additions ex- plained,	32 33
Illustrations.—Experiment of a sponge in water,	33
Experiment of a hyacinth growing in water,	34
Experiment of iron swelled by heat,	35
Independent powers of motion in living things,	36
Our ignorance of the nature of life,	37

CHAPTER II.

ON THE INDIVIDUALITY OF ORGANIZED BEINGS, AND THE DIFFUSION OF
LIFE IN LIVING BODIES.

Peculiar powers of life enjoyed by every organ,	38
Explanation of the terms function and vital functions,	39
The mutual dependence of parts and their functions,	40
The various degrees of importance of different organs,	41
The power of healing injuries is inversely as the complexity of the organization,	42, 43
Illustrations.—Life in the amputated tail of a snake, the hind legs of frogs, and the heads of turtles—life in tortoises without brain or heart, and in the disembowelled shark, . .	45
Diffusion of vital power in simple animals,	46
Organization of animal and vegetable fluids—explanation of the term assimilation,	47 48
The nutritive fluids are possessed of life,	48
The simplicity of the fluids corresponds with the simplicity of the solid structure of organized beings,	49-51
Illustration.—History of a medusa,	52-55
Independent life of pieces cut from animals of very simple organi- zation,	56
History of the hydra viridis—the type of simplicity in animal organization,	57
Digestion in the hydra,	58
Absorption in the hydra,	59
The great cavity of the hydra answers the double purpose of a stomach and a heart,	60
The hydra, when inverted, continues to live,	61
Multiplication of the hydra by artificial division,	62
Spontaneous division of the hydra,	63

	Paragraph
Limits of the divisibility of the hydra,	64
Uniformity of structure in the hydra,	65
Explanation of the terms cellular membrane and cellular tissue,	66, 67
Structure of cellular tissue,	68
Illustrations.—Inflation of fowls for market,	69
Effects of a fractured rib wounding the lungs,	70
Structure of fat—explanation of the term adipose tissue,	71
Vital functions of the hydra,	72–77
Animals distinguished from vegetables by consciousness and will,	78

CHAPTER III.

ON THE ORGANIZATION AND FUNCTIONS OF SIMPLE ANIMALS, APPARENTLY
DIVESTED OF SPECIAL ORGANS.

Minuteness of simple beings necessary to the preservation of the race,	79
Simple beings—why confined to fluids,	80
Fixedness of many simple animals—their means of taking prey—tentaculæ,	81
Means of taking food—cilia,	82
Cilia and tentaculæ of <i>flustra carbacea</i> ,	83
Cilia are sometimes organs of locomotion— <i>vorticella cyathina</i> ,	84
Contractility—motion of cilia not muscular,	85
Motion of cilia in respiration of larger animals,	86
Cilia in plants— <i>chara hispida</i> ,	87
Gemmules— <i>gemmules of flustra</i> ,	88
Polypi commonly live in families and have a common life,	89
Necessity for mechanical support in simple animals,	90
Several forms of calcareous or horny support,	91
Madrepore—effects on navigation,	94
Secretion—as seen in polypi, cuticle, shells, &c.,	96
of lime and horn common to all animals and, probably, to parts of animals,	98
Nutrition a kind of secretion,	99
Secretions sometimes act as motive powers—bile,	100
Functions of organic and animal life,	101
Contractility moves the fluids,	103
differs from inorganic contraction, which is the result of cohesive attraction,	104
instances of—visible in plants and as displayed in <i>physalia megalista</i> ,	105
mode of taking prey in <i>physalia</i> , and its mode of locomotion,	106
not necessarily dependent on will,	110
must be excited by some agent,	112
Contraction results from the action of stimulants,	113
Tonicity,	114
diminished or destroyed by paralysis, fainting and sleep,	116

	Paragraph
Tonicity—influenced by heat and cold,	117
of skin,	118
Various forms of tonicity—are they all due to the same cause? .	119

CHAPTER IV.

ON THE NECESSITY FOR A MASTICATORY AND DIGESTIVE APPARATUS IN
COMPLEX ANIMALS.

Simplicity of the elementary stomach,	121
Necessary division of the stomach in the medusa,	122
The ramifications of the stomach in medusa seem to supply the place of blood-vessels,	123
Necessity for greater complexity as we ascend the scale—masti- catory apparatus,	124
Early appearance of teeth and jaws—teeth and jaws in echinoder- mata and in insects,	125
Internal masticatory organs,	126
Alimentary canal,	127
Gizzards,	128
Digestive apparatus—more simple in carnivorous animals,	130
of shell-fish complex,	131
simple in birds of prey, and complex in beasts that live on vegetables,	132

CHAPTER V.

ON THE NECESSITY FOR A SPECIAL APPARATUS OF MOTION. THE MUSCULAR
AND OSSEOUS SYSTEMS AND THEIR APPENDAGES.

Necessity of a muscular system,	133
Muscular system,	134
Muscles of voluntary motion,	135
Necessity and existence of involuntary muscles,	136
Muscles of organic and animal life,	137
Mixed muscles,	138
Fascia,	139
Fascial system,	140
Uses of fasciæ,	141
Structure of fascia,	142
Appearance of muscles—they are identical with flesh,	143
Arrangement of separate muscles,	144
Structure and colour of muscles,	146
Muscular fibre—structure of,	148
Cellular nidus of muscles,	149
Muscles between fragments of bone reduced to cellular tissue, ..	150
Attachments of muscles,	151
Cutaneous and fascial attachments of muscles,	151
Testaceous attachments,	152

	Paragraph
Attachments in echinodermata,	153
Attachments in insects and crustacea,	155
External skeletons and appendages of the skin,	156
Necessity for an internal skeleton in more complex animals— osseous system—bones,	157
Attachment of voluntary and mixed muscles to bones,	158
Cartilaginous condition of bones in young children and quad- rupeds, and in certain fishes,	159
Earthy material of perfect bone,	160
Condition of bone when deprived of cartilage,	161
Condition of bone when deprived of earth,	162
Reduction of bone to cellular tissue by art,	163
Reduction of bone to cartilage or cellular tissue by disease,	164
All organs reducible to cellular tissue,	165
Cellular tissue the constructor of all the organs,	166
Reunion of wounds always effected by cellular tissue,	167
The power of cellular tissue to form different organs is a mys- tery,	168
Necessity of cartilages at the joints,	169
Articular cartilages,	170
Synovial membranes and fluid,	172
Necessity for ligaments to bind the joints,	173
Structure and functions of ligaments,	174
The envelope of bones called periosteum,	175
Extent of the periosteum—explanation of the terms perios- teum, perichondrium and pericranium,	176
Recapitulation of the parts and appendages of the osseous system,	177
Necessity for tendons or parts accessory to the voluntary mus- cles,	179
Form and arrangement of tendons,	180
Involuntary muscles rarely have tendons—generally hollow— muscular coat of alimentary canal,	181

CHAPTER VI.

ON THE GENERAL DIVISIONS OF THE VASCULAR SYSTEM.

Necessity for the existence of blood-vessels,	182
Of the veins,	183
Tendency of the venous blood to a common centre.—Valves of the veins,	184
Different forms of the common centre.—The heart,	185
Conduits for the blood running from the common centre or heart, called arteries,	186
Communication between the arteries and the veins.—The capillaries,	187
The circulation,	188
Gradual developement of distinct systems of organs as the scale of animal organization rises,	189

	Paragraph
Partial circulation in insects,.....	190
Circulation, in the earth-worm, leech, marine worms, and shell-fish,	191
Aliment in the hydra, &c. taken into the body by imbibition, ...	192
The absorption of the nourishment from the chyme in insects, worms, &c., is probably by a double imbibition,	193
Assimilation not complete when the nourishment or chyle is first imbibed, <i>but is perfected in the blood-vessels</i> ,	194
Set of vessels, called the lacteals, for conveying the chyle to the blood-vessels,	195
Colour and structure of chyle,	196
Origin of the lacteals.—Uncertainty of the question whether they absorb by imbibition.—Their resemblance to roots.—Their structure and route to the veins,	197
The agency of the lacteals in destroying the power of independent life in the parts of the more complex animals when divided,	200
The lacteals not the only route by which substances from without find their way to the blood.—Cutaneous, cellular, and venous absorption by imbibition in the most perfect and complex animals,	201
The lymphatics or absorbents.—Characters of lymph,	203
Proofs that the lymphatics convey substances to the blood,	204
Objection to the term absorbents, as applied to the lymphatics, ..	206

CHAPTER VII.

OF THE FUNCTIONS OF SECRETION, RESPIRATION, AND NUTRITION.

Recapitulation of the scale of gradual complication in the nutritive organs,	207
Question why food is required to support the frame after an animal has reached maturity,	208
Waste by perspiration in plants and animals.—Insensible perspiration,	209
Perspiration from the cavities.—Moisture of breath,	210
Respiration considerable in amount.—A secretion furnished from the blood,	211
Waste of the blood by the numerous secretions.—Much food required to compensate it,	212
Many fevers diminish the secretions and the waste of the circulation—hence the impropriety of giving much food in fevers,	213
During starvation a man lives on himself,	214
Diminution of all organs and the destruction of some less important ones, by abstinence,	215
All the particles discharged from the body are taken up by the absorbents, carried into the circulation, and discharged by secretion,	216
Absorption of particles carried on continually, even in health	

CONTENTS.

xvii

Paragraph

—reasons why the size of the organs is not diminished there- by,—and why they grow larger during adolescence,.....	217
The particles of the whole body totally changed every few years—hence the continued necessity for food,.....	218
The constant accumulation of worn-out particles in the blood requires a purification of that fluid.—This office performed by means of the secretions,.....	219
Numerous secretions of complex animals,.....	220
Folly of reasoning on the ultimate <i>causes</i> of vital phenomena,	221
Arrangement of the blood-vessels in secreting organs.—Mu- cous membrane,.....	222
Secretory glands,.....	223
Arrangement of capillaries in secretory glands,.....	224
Structure of the ducts of the secretory glands,.....	225
Proofs of transpiration from the blood-vessels into the ducts of glands,.....	226
Economical uses made of many secretions—tears, saliva, and bile,	227
Of respiration,.....	228
Principal object of respiration,.....	229
Principal ultimate elements of animal organization,.....	230
The surplus carbon of the blood requires to be discharged by a special apparatus.—Partly discharged by the liver in the secretion of bile, but not sufficiently,.....	231
Carbon discharged from the blood in the form of carbonic acid, whenever the blood in living blood-vessels approaches very near to the atmospheric air. This product always pro- duced by respiration,.....	233
Animals that live in water, respire the air combined with the water,.....	234
Too great a supply of air kills a fish, and exposure to pure oxygen soon kills the more perfect animals,.....	235
Actual contact with air not necessary to purify the blood.— Respiration effected by imbibition, and transpiration,.....	236
Cutaneous respiration of the simpler animals,.....	237
Cutaneous respiration in man,.....	238
Mode of respiration by special apparatus,.....	239
Resemblance of respiratory organs to secretory glands,.....	240
Tracheal respiration of insects, &c.,.....	241
Aquatic respiratory apparatus,.....	242
Branchial respiration,.....	243
Great variety of form in branchiæ—all constructed on one prin- ciple,.....	244
Agency of cilia in branchial respiration,.....	245
Pulmonary respiration,.....	246
Simplest forms of pulmonary organs,.....	247
Arrangement of the lungs in the larger animals.—Right and left lungs,.....	249
Structure of the air passages in such animals,.....	250
Names of the principal air passage and its ramifications,.....	251
Resemblance of air passage to the ducts of secretory glands.— —Their structure,.....	252

	Paragraph
Apparatus of inspiration.....	253
Air passages in the bones of birds,.....	254
Pulmonary and branchial respiration of reptiles,.....	255
Partial respiration of inferior animals,.....	256
Feebleness and slowness of vital functions in animals with partial respiration.—Amphibia,.....	257
Perfect respiration and activity of function in man, quadrupeds, and birds,.....	258
Respiratory and nutritive vessels of the respiratory organs, and the distinct routes of circulation in them.—Nutritive and respiratory systems of vessels,.....	259
Systematic circulatory apparatus an objectionable term.—General or nutritive system or apparatus preferred,.....	260
Description of the heart,.....	261
Functions of the auricles and ventricles,.....	262
Description of the route of the circulation,.....	263
The heart is generally a double or quadruple organ,.....	266
The circulation of all animals is single and not double,.....	267
Interlacement of the blood-vessels.—Route of circulation when vessels are obliterated,.....	268
Danger of an obstruction in a large artery.—Death of a part inevitable when the circulation through its vessels is totally arrested for some time,.....	269
Not only the life, but the activity of function in a part, depends on the number and size of its blood-vessels and the quantity of blood that passes through it,.....	270
Activity of the functions of muscles when compared with tendons.—Why the rapidity of the heart's action increases by exercise—also the rapidity of the breathing,.....	271
Effects of exercise in enlarging muscles,.....	272
Effects of rest in diminishing or destroying them,.....	273
Generality of the law that habitual functional activity increases power, and habitual repose diminishes it in all the organs.—Moral deduction,.....	274
Necessity for the alternation of repose and rest to promote nutrition,.....	275
Of the effects of sleep at different ages,.....	277
Danger of over-exertion, and its effects on nutrition,.....	278
Effects of over-wrought labour and want of sleep.....	279
Agency of the organs themselves in perfecting assimilation,....	280

CHAPTER VIII.

ON THE NERVOUS SYSTEM.

The variety of vital actions often performed in producing a single effect, renders necessary a bond of communication between the different organs,.....	281
First appearances of the nerves in the inferior animals,.....	282
Cineritious and medullary matter of the nervous system,.....	283

	Paragraph
Structure of the brain, and the terminal connections of nervous filaments,.....	284
Cellular tissue of the nervous system,.....	285
Nervous ganglia.—Nervous filaments of the brain and ganglia.	
—Functions of the ganglia,.....	287
Structure and function of a nerve.—The neurilema,.....	289
Compound nerves with compound functions.—Each nervous fibre a distinct organ with a special function,.....	291
Origin and association of the nerves of motion and of feeling.	
—Effects of dividing them,.....	292
Formation of a nervous plexus,.....	293
Forming and resulting nerves of ganglia,.....	294
Arrangement of nervous filaments in ganglia,.....	295
Influence of the ganglia upon the functions of the filaments,...	296
Complex structure of most organs.—Extensive diffusion of nervous filaments and nervous influence.—The functions of organs controlled by nerves,.....	297
Divisions of the nervous system.—Nervous systems of organic and animal life,.....	299
Irregular distribution of the nerves of organic life, and irregular form of the organs controlled by them,.....	301
Regularity of the nerves of animal life and the organs controlled by them,.....	303
Position and curious functions of the great sympathetic nerve in health and disease,.....	304
Dependence of the nerves upon the capillary blood-vessels,....	311
Mutual dependence of all parts of the frame upon each other...	312
Difference of plan observed between the nervous systems of animals with an internal, and those with an external skeleton—Particularly in relation to the brain,.....	313
Still greater imperfection of the nerves in animals of yet lower grade,.....	314
Consequent impossibility of comparing the differences of intelligence between one great class of animals and another, by reference to the structure of the brain or nervous system, .	316
Remarks upon the impropriety of the term— <i>The scale or chain of animated nature</i> ,.....	318

CHAPTER IX.

OF THE SURFACES OF THE BODY.

Great divisions of the human body into head, neck, trunk and extremities,.....	319
Division of the head into the cranium and face,.....	321
Division of the trunk into chest, abdomen, and pelvis,.....	324
Divisions of the extremities,.....	328
Cellular structure of the whole body,.....	331
Of the integuments,.....	333

	Paragraph
Of the cuticle or epidermis,.....	336
Of the supposed pores of the skin,	340
Of the sebaceous follicles,	342
Connections of the hair with the cuticle.—Growth of hair,....	344
Functions of the cuticle,.....	348
Of the rete mucosum.—Of the colouring matter of the rete mucosum, and the effects of climate and seasons on the skin and hair,.....	350
Of the true skin or cutis vera,.....	353
Of the structure and functions of cutis vera, and the papillæ,..	355
Of the fleshy panicle or muscular layer of the skin,	358
Of the mucous follicles,	360
Connections of the skin.—Arrangement of the sub-cutaneous cellular tissue and fat,.....	362
Universality of the covering of integuments,	365
Of the epithelium.—Inward reflections of the integuments.— Modifications of the internal integuments,.....	366
Of the pharynx, and the muscular coat of the internal integuments,	368
Of the termination of the epithelium, and the structure of the mucous membranc of the alimentary canal,.....	369
Of the villi,.....	371
Of mucous glands or collections of follicles,	372
Formation of the ducts of secretory glands by the integuments. —Lining of the air passages, &c.,	374
Formation of accidental canals by the integuments,.....	375
Mutual convertibility of the internal and external integuments, .	376
Extent of the integuments and the surface,.....	379
Effects of the absence of cuticle on the internal surface,.....	380
Concentration of sensibility at the origin of canals,	381
Vicarious action of the lungs and skin,	383

CHAPTER X.

OF THE SKELETON AND ITS APPENDAGES.

Growth and general arrangement of the bones,.....	384
Tabular and cancellated structure of the cranium,	388
Walls, cellular structure and cavities of the long bones,	389
Cellular tissue of bone, and medullary membrane,	392
Structure of the solid portions of bone.—Use of the canals,....	394
Blood-vessels of the bones,	395
Nervous sensibility of the bones,.....	396
Validity of bone proved by its diseases,.....	397
Bony structure of the head,	398
Form of the cavity of the cranium,.....	399
Of the frontal bone,.....	400
Of the frontal sinuses,.....	401
Of the orbital plates,	404
Of the part of the brain covered by the frontal bone,.....	405
Of the parietal bones,.....	406

	Paragraph
Of the parts covered by the parietal bones,	407
Of the occipital bone,	408
Of the cuneiform process,	408
Of the great foramen,	409
Of the occipital cross,	410
Of the temporal bones,	413
Of the petrous portion of the temporal bone,	414
Of the mastoid process of the temporal bone,	415
Of the sphenoid bone and cells,	418
Of the ethmoid bone,	419
Of the sutures,	420
Condition of the cranium during childhood, and its consequence,	421
Changes of cranium from the progress of age,	426
Good consequences of the arched form of the cranium,	427
Articulations of the cranium with the atlas vertebra,	428
Of the atlas vertebra,	429
Definition of the term condyle,	430
Articulations of the cranium and atlas with the vertebra dentata,	431
Of the limits of the motions of the head,	434
Of the bones of the face,	438
Of the upper jaw and its nerves,	439
Sympathetic connections between the teeth, the ear and eye,	441
Of the teeth,	442
Of the socket processes.—Of the enamel,	443
Of the periosteum of the teeth,	444
Of tooth-ache from inflamed periosteum,	445
Of the absorption of the socket,	446
Of the shedding of the infantile teeth,	447
Of the language of the teeth in relation to diet,	448
Of the sympathy between the stomach and the teeth,	455
Of the spine,	457
Great divisions of the spine,	458
Of the bodies and processes of the vertebræ,	459
Of the articulations of the spine, and the intervertebral fibro- cartilages,	461
Of the ligaments and spinal canal,	463
Of the mobility of the spine,	464
Of some effects of caries, rheumatism, &c. of the spine,	466
Of the number and articulations of the ribs,	468
Of the cartilages of the ribs,	469
Of the sternum and its connections,	471
Of the motions of the ribs and sternum,	472
On some of the effects of mechanical restraint of those motions,	475
Of the pelvis.—Of the sacrum,	480
Of the os coccygis,	481
Of the ossa innominata,	482
Of the bones of the superior extremities,	483
Of the scapula and clavicle,	484
Of the shoulder-joint,	487
Of the humerus,	489
Of the elbow-joint,	490

	Paragraph
Of the ulna,	491
Of the radius,	492
Of the motions of the forearm,	493
Of the wrist and hand,	494
Of the bones of the inferior extremities. Of the hip-joint,	500
Of the head and neck of the femur and its changes,	501
Of the tibia and fibula, the patella and the knee-joint,	506
Of the ankle-joint,	509
Of the tarsal bones and bones of the foot,	510
Of the ligamentous and muscular support of the skeleton,	513
Of the effects of the inelasticity of certain parts of the skeleton,	514

CHAPTER XI.

OF MUSCULAR STASIS OR EQUILIBRIUM.

Three predicates of the argument on muscular equilibrium, . . .	519
On deformities produced by muscular action or debility,	522
On deformity from using the right hand,	522
On deformity from using the left hand,	524
On the train of deformities resulting from club-foot,	525
On the train of deformities consequent upon sitting long erect without support,	529
Vices of figure from certain errors of school discipline, . . .	531
Causes, effects, and cure of an habitual stoop,	535
On deformities of the eye, and vices of vision from a change in the equilibrium of the muscles of the eye,	539
On muscular equilibrium between the muscular fibres of or- ganic life,	546
On the reaction of the stomach and pylorus,	547
Effects of the habitual and undue distension of muscular cavities.—Influence of this habit on digestion,	550

CHAPTER XII.

OF THE GREAT CAVITIES OF THE BODY.

Of the muscles and fleshy walls of the thorax,	554
Of the diaphragm,	560
Of the serous cavities of the thorax,	563
Of the pleuræ,	565
Of the pericardium,	566
Of the position of the lungs and heart,	568
Of the structure of the larynx,	569
Of the fleshy walls of the abdomen,	577
Of the serous membrane of the abdomen, or the peritoneum, and its arrangement,	580
Of the position of the liver, gall-bladder, and spleen,	585
Divisions of the alimentary canal in the abdomen,	590
Of the stomach and its cardiac and pyloric extremities, . . .	591

CONTENTS.

xxiii

	Paragraph
Of the duodenum, and the pancreatic and biliary ducts,	593
Of the small intestines,	594
Of the cœcal valve,	596
Of the cœcum and colon,	597
Of the vena portæ and portal vessels,	599
Functions of the portal vessels,	600
Effects of compression on the circulation in the portal system, .	601

CHAPTER XIII.

OF THE MECHANISM OF BREATHING.

Action of the muscles of the chest in inhalation,	605
Action of the diaphragm and abdominal muscles in inhalation. —Movements of the abdominal viscera and heart,	609
Forces producing exhalation,	610
Effects of muscular debility on breathing,	611
Action of the abdominal and cervical muscles in difficult breathing,	612
Effects of mechanical restraint on breathing,	613

CHAPTER XIV.

REMARKS ON DIGESTION AND THE CIRCULATION.

On the importance of mastication,	619
Effects of loss of tone on digestion,	622
Phenomena attendant on stomachic digestion.—The siesta,	624
Water probably absorbed from the stomach by the veins,	625
Duodenic digestion.—The peristaltic motion,	626
Effects of poisons and emetics.—Erroneous notions about bilious- ness,	627
Structure of the blood-vessels,	630
Essential or serous coat of blood-vessels,	630
Thick fibro-cellular coat of blood-vessels,	631
Middle or fibrous coat of the arteries.—Its functions,	632
Effects of active exercise on the circulation,	634
Effects of passive exercise on the circulation,	639

CHAPTER XV.

ON THE FUNCTIONS OF THE NERVES AND BRAIN.

Proof that the function of a nervous fibre resides in all parts of the fibre,	640
Proof that consciousness and will do not reside in the nerves of the senses,	645
General description of the brain and its membranes,	648
Argument to show that consciousness and will are not functions of the organization,	659

	Paragraph
Proof that the display of the mental functions does depend on the organization of the brain,.....	668
Question of a common centre of the nervous system or a sensorium commune,.....	669
Ganglionic character of the brain,	670
Gradual development of the brain in ascending the scale of organization in the vertebrate animals,.....	672
Gradual progress of the development of the brain from infancy to age,.....	675
Fundamental principles of phrenology.—Their occult character,	680
Of the spinal marrow—its position and extent,	681
Internal arrangement of medullary and cineritious matter, .	682
Distribution of the fibres of the spinal marrow to the brain,	686
Proof of the existence of divergent nervous fibres entirely confined to the brain,	690
Membranous arrangement of the convolutions of the brain,	691
Proper mode of investigating what are the functions of the nerves of the brain.—Errors of the phrenologists,	692
Phrenology not dependent on cranioscopy.—Origin of cranioscopy,	703
Sources of error in cranioscopy,	707

CHAPTER XVI.

OF TEMPERAMENTS AND IDIOSYNCRASY.

Nature of temperaments,	710
Of the sanguine temperament,.....	717
Of the bilious temperament,.....	722
Of the lymphatic or phlegmatic temperament,.....	724
Of the nervous temperament,	725
Of a peculiarity of temperament in women and children,	727
Changeability of temperament,	728
Of peculiar temperaments of particular organs, and their connexion with idiosyncrasy,.....	730
Questions for pupils,.....	305
Glossary,	334

PHYSIOLOGY FOR SCHOOLS.

CHAPTER I.

ON THE MOTION AND GROWTH OF ANIMATE AND INANIMATE BODIES.

1. WHEN we examine the great mass of *things* which nature continually presents to our observation, we soon learn to classify them into *things which have life*, and *things which have not life*. Now what constitutes the difference between these two great classes of things?

2. The first living things which strike the attention of an infant, are observed to move from place to place with perfect freedom, and thus his earliest notion of life is connected with motion. His mother's lap-dog or his favourite kitten goes to sleep upon the hearth-rug, and the child is alarmed lest it be dead. His father holds a watch to his ear; he sees the second-hand jerking and turning round, he hears the click corresponding with every jerk, and very naturally inquires, "Is it alive?" He soon learns, however, that *to seem to be still is not to be dead*, and that *to move is not always to be alive*.

3. Still, he finds it difficult to separate entirely the ideas of motion and life in many cases. He knows that the trees are living, even when not a leaf trembles in the quiet air of a summer noon. "The wind does not blow, and why should they move?" Yet I have known many intelligent youths who, though they would blush to be called uneducated, were extremely puzzled with a very simple experiment. When an eye-stone, as it is called, is placed on a smooth plate, with a little weak

vinegar, it is soon surrounded by small bubbles of air, which escape from beneath it, and it gradually moves from place to place, seeming to crawl round the plate. I have often known these bubbles to be mistaken for legs, and the eye-stone for an animal. It is, in truth, nothing but a plug or door, constructed by a peculiar kind of marine shell-fish, to shut out unwelcome visitors when the animal wishes repose. It scarcely differs in nature from limestone or marble, and either of these substances, if cut into the same form, and polished, will behave in the same manner: any chemist will tell you why.

4. Perhaps next to *motion*, the phenomena of *growth*, as witnessed in living things, arrests most forcibly the attention of the child. He sees that he is small, and that his parents are much larger: they inform him that they were once as small as he. His own growth, from day to day, becomes a matter of pride with him, and he sighs for the time when he shall be as large and strong as his father, that he may be able to protect his mother, his sisters, and himself. The shrub in the garden, the grass in the field, and the leaves and branches on the trees, all put forth in his presence, and gradually assume their proper form and size. He is told that these things are alive, and naturally concludes that *whatever grows has life*.

5. But here, again, his ideas are soon confused by newly acquired facts. On the one hand, he observes that plants and animals, or, in other words, all things which have life, continue to live even after they have ceased to increase in size; and, on the other, he perceives that many things which, as he is told, *are not alive*, are seen to grow; so that he is not always able, if not instructed, to perceive the difference between the *growth of a living thing, and that of a thing which is not alive*.

6. When very young, he may observe the icicles, pendent from the eaves of houses, gradually increasing in length by a process which he does not understand. Sometimes even this simple phenomenon has been mis-

taken for the result of life; but the error is confined to that early period of infancy when the fall of snow is attributed to "*the Welshman picking his geese.*"

7. At an age a little more advanced, the child observes, perhaps, that the flowers in the vase on the mantel-piece continually drink up the water in which they are placed; and, as they drink, their young leaves grow longer, and their buds expand. He places his dry sponge in a basin, and he observes that it slowly draws in the water which surrounds it, and, as it does so, swells out until its bulk is prodigiously increased, and its form entirely altered. Now there is sufficient resemblance in these two occurrences to lead the very young inquirer to ask wherein consists the difference. I have heard the question not unfrequently, and always from the most intelligent children.

8. But, my young readers may remark, we are no longer such children, that we need be cautioned against these mistakes. Perhaps not. Yet there are others of a similar nature which occasionally confuse heads much older than yours. You have read of the beautiful incrustations of brilliant spars which hang from the roofs of caves in many parts of the world. The island of Antiparos, for instance, the Peak of Derbyshire, or the mountains of Virginia. You know that these spars are continually growing, and that they not unfrequently assume a rude resemblance to animals and plants. Again; if you have ever been in an old and damp house, you may have seen the plastered walls covered with patches of saltpetre. This mineral substance shoots out into a delicate efflorescence so nearly resembling moss and mould, that you must examine closely before you can distinguish it from them. Moss and mould are true plants, which may be sometimes seen growing on the woodwork of the same apartment. If you brush away both the mould and the saltpetre, they will soon grow again, side by side, so that you can scarcely be blamed for mistaking the one for the other. In the neighbourhood of certain iron-works, where the ore is of a peculiar quality, lying in low and damp

ground, it is sometimes entirely exhausted by the demands of the furnace; yet, after the place has been deserted for a few years, in consequence of the failure of the supply, the proprietor is surprised to find a new bed of ore in the old place; and the operation of the works is then profitably renewed.

9. Now the facts just mentioned, and others which resemble them, produce a vague impression that rocks and stones possess a kind of inherent power of increasing their own dimensions; a power which, from our last deduction (4), seems to belong exclusively to *living things*. You may be already too well informed to entertain such a strange opinion, but you must now be prepared to grant that *not all that grows has life*.

10. Motion and growth are the only phenomena which strike the eye of the youthful observer, as exhibited by all living things without exception; and these, as we have seen, are insufficient in themselves to furnish a distinction between such things and those which have not life.

11. Birth and death are often mentioned as peculiarities of living things; but *birth is but the beginning of independent life*, and *death is but the end of life*. Neither of these are *properties* of living things; for *birth* has passed away the moment any thing begins to live independently, and the thing must cease to live the moment that *death* occurs. I wish to confine your attention in this chapter, to things as they are — not as they have been, or will be hereafter. Although neither motion nor growth, which is but the result of a very slow motion, are confined to living things, we must endeavour to find such peculiarities in the motion and growth of these things as will enable us to distinguish them from those which have not life. By so doing, we shall take our first step in the study of PHYSIOLOGY, which is the name given to the science that *treats of the actions of living things and the parts of which they are composed*.

12. I must take it for granted that you have already acquired a knowledge of the laws of attraction; that you are aware of all we know of the reason why a

stone falls to the ground, and why a spring, when bent, flies back, and continues vibrating for some time. If you are ignorant of these things, inquire of your teacher or your parents; for an acquaintance with the laws of attraction, as displayed by inanimate matter, is a necessary prerequisite to the comprehension of the simplest physiological facts and doctrines.

13. Then, let us examine wherein the motions observed in living things differ from such as characterize those things which have not life. The latter have no power of moving by their own energy or will. Their changes of form and position are all the result of forces which act upon them from without. They must be placed under the influence of *other things* before they can alter their condition in the slightest degree. Let us give some examples. A stone would not fall to the ground, were it not that it is attracted towards the earth, and the earth towards it. The spring could never vibrate in consequence of the attraction of its particles for each other, were it not that the hand, or some other external agent, has previously bent it from its natural position. It cannot vibrate of itself. The force with which it recoils is never greater than that which is applied to bend it; and when this is expended it ceases to move. The watch (2) no longer clicks, and its hands are at rest, the moment that the spring has lost the curve communicated to it by the key. The eye-stone (3) cannot crawl around the plate without the presence of the acid, which, as your preceptor will tell you, if you have not studied chemistry, combines with a part of its substance, disengaging from it a kind of air or gas. This gas, by escaping in bubbles from beneath the stone, pushes it along. When all the acid of the vinegar has combined with the eye-stone, leaving nothing but the water and the dissolved portion of the stone around it, its motion ceases, because no more gas escapes.

14. Now living things are moved in the same manner by external causes; for, if a man be hanged and the rope break, he will fall to the ground like a stone: if

the limb of a tree be bent by the wind, it will fly back and vibrate like a spring. But there are other kinds of motion observed in living things, that are never seen performed by things which have not life.

15. Most of you may have seen potatoes sprouting in a dark cellar. If so, you may have noticed how all the young roots take their course towards the nearest moist earth, and how regularly and rapidly the tender vines crawl toward the crevice in the wall which admits the strongest light. There are persons who will tell you that the roots are *attracted* by the water, and the stems by the light; but such persons have a very vague idea of the meaning of the word *attraction*, as employed by philosophers. Your preceptor can inform you, or, when you become acquainted with the elements of mathematics and natural philosophy, you can inform yourselves, that light, which is an imponderable substance, cannot exercise an appreciable attractive power upon even the most minute particle of matter that is capable of being weighed by human hands. There must therefore exist in the living vine and roots some internal and inherent power by which they move in certain directions in preference to others, as if by volition—a power that is not the result of actual forces from without, such as produce the motions of inanimate matter.

16. All living nature teems with evidences of motion originating from internal power of this kind, by means of which every thing that has life undergoes changes which can never be imitated by inanimate matter. I will mention a few striking examples. The leaves of almost all plants turn their upper or deep green surfaces to the light, and follow, with more or less regularity, the apparent motion of the sun in his daily route.

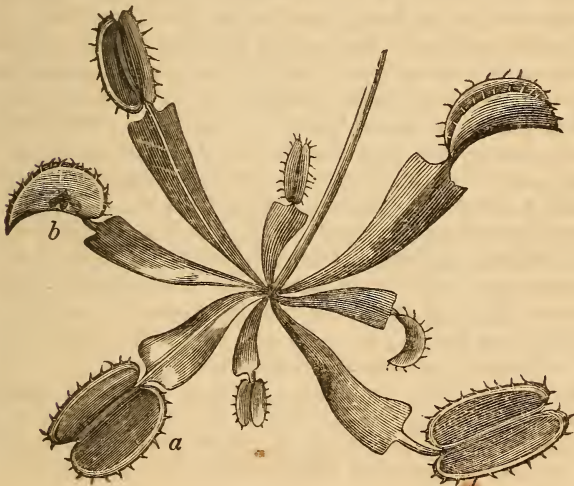
“The sunflower turns on his god when he sets
The same look that he turned when he rose.”*

Most flowers open their petals in the morning, and shut

* Although the propensity of the sunflower to follow the course of the sun is only remarkable when the plant is in vigorous health, and is even then imperfectly displayed in many cases, any one who will compare the direction of the same flower at ten in the morning and five in the afternoon, will be convinced that this propensity is no poetical fiction.

them in the evening, to protect the more tender parts from the night dews and the cold; the primrose prefers unclosing in the twilight, and folds its delicate veil in the morning to exclude the heat; while the night-blooming cereus displays its glories only to the moon and stars, expanding at the "noon of night," and fading before it sees the day. Most of you may have seen the sensitive plant, of which not only the leaves, but even the branches recoil the moment we touch them. The plant called Venus's fly-trap, (*Dionæa Muscipula*,) has a part of the extremity of its leaves constructed somewhat like a steel-trap, which closes instantly and crushes or imprisons any small insect which has the rashness to alight upon it. In fig. 1, you are presented with a sketch of this curious plant. At *a*, you see a leaf expanded, and the darker part, situated in the centre, cannot be touched in the gentlest manner, while the plant is vigorous, without causing the leaf to close. At *b*, you see a leaf that has entrapped a fly.

Fig. 1.



Venus's Fly-Trap.

17. In animals, we observe still stronger evidences of motions originating from internal causes; for every known animal enjoys the faculty of *will*, and changes its form or its attitude to suit its own convenience. Till within a few years, some learned naturalists believed that many of the simpler animals were deprived of will and feeling, but more recent discoveries have proved the error of this opinion.

18. I think you will now be prepared to grant that living things possess a power of regulating their own motions to a certain extent: that they seek what they require, whether it be light, heat, water, or comfort, by powers peculiarly their own. But if you be still inclined to doubt this proposition,—and it would not be unnatural for you to do so in the case of plants, which are deprived of will and feeling,—you will soon be convinced in the sequel. Now, no such power is possessed by any thing that has not life: and here you see a broad and clear distinction between the two great classes of things mentioned in the beginning of our argument.

19. The power of which we are speaking evidently resides within the living thing which is endowed with it; and, as it produces mechanical motions, there must be within every thing which has life an *apparatus*—a machine to produce these motions;—for no mechanical effect can be produced without a machine. But almost every living thing performs various different acts; and a machine which is intended to perform various acts, is usually composed of many different parts. Let us take a rose-bush for an example. It has a root to supply it with nourishment, a stem and branches to support the leaves and flowers, seeds to produce other rose-bushes in succession, &c. Again, from among animals let us take a cricket. It has wings to fly and sing with, legs to leap with, jaws to eat, and a stomach to digest its food with, eyes to see with, antennæ, or feelers, in which reside the sense of touch, and, perhaps, the power of conveying its ideas, &c. Now each of these parts of the machine, which performs some distinct act or purpose, is called an *organ*.

20. But things which have not life perform no such independent motions or acts; they therefore have no organs. For this reason it has become customary to distinguish things which have life by the title of *organized beings*.

21. You may naturally suppose, since organized beings are endowed with powers superior to those which have not life, that the former class of things must be formed of a different kind of matter from that of which the latter are constructed; but this is not the case. All the parts of a living or organized being, and all the materials for its growth and support, are derived from the general mass of things which have not life. Yet this *matter* must be arranged in a totally different *manner* from that in which it is found before it becomes possessed of life; for otherwise it could not be fitted to perform such different offices: and here I must give you another definition. The peculiar arrangement of the matter which forms a living thing, is called its *organization*.

22. You know that when an organized being dies, it soon begins to decay; but one part decays much faster than another. The wood of a dead tree long outlasts the bark and the leaves, and the bone of an animal remains when the flesh and skin have disappeared. Sometimes we can see the disorder in the organs which produces death, but on other occasions it cannot be discovered, and in such cases no perceptible change takes place in the organization of the dead tree or animal for a considerable time. Yet the mysterious principle of life,—the power which kept the machine in motion,—has departed, we know not why. We can no longer call the body, or the part of it which has not yet decayed, an organized or living being, for its life or being has escaped from it. But its organization still remains, wholly or in part. Its arrangement is such as life alone could effect, and death itself cannot instantly destroy. These remnants of things which have had life are still organized, though dead, and are very different from things which never had life: they cannot return to the condition of these latter things until they have become

entirely decayed. You will now understand why we divide all matter, whether dead or living, into two great classes: *organic matter*; which has life, or has had it so recently as not entirely to have lost its character; and *inorganic matter*; which never had life, or which has been so long dead as to have lost all traces of its former organization.

23. Sometimes the whole or a portion of an organized being becomes buried in the earth or inclosed in rocks, during great convulsions of nature, or during the slow deposition of the stony matter which is often dissolved by the waters of springs, streams, or floods; and the forms of such beings are continually found in the bottoms of old caves, in solid rocks, and other similar situations. These remnants often preserve a part of the organic matter of which they were formed when alive. Thus, the bones of the mammoth of America, so constantly discovered about the salt-licks of the western country, and sometimes even in the sands of New Jersey, are always found to contain a considerable portion of animal matter, though ages have passed since their death. The same remark is true with regard to the bones of the rhinoceros, the tiger, the hyena, &c. so often found in countless numbers in the bottoms of caves in Europe. But most of the shells which form a large portion of certain limestone and other rocks, and which we commonly call *petrifications*, have lost entirely the matter of which they were once composed. This has been washed away, and another substance deposited in the cavity thus made in the rock; so that the form alone is preserved, and the petrification is composed entirely of inorganic matter. On the coast of Florida there are found whole reefs of coral that were once constructed by myriads of minute animals living in the sea, and were then composed principally of lime. These reefs have been lifted up from the water by some earthquake, or other great convulsion of nature, occurring many hundreds, perhaps thousands of years ago. They still retain all the delicate forms of coral, though apparently converted into beautiful calcedony or cornelian, which

is a kind of precious stone composed chiefly of silex or sand. Even the softer parts of animals and plants are often thus completely petrified; but though all their organic matter has decayed and past away, these casts of things which once had life are still known to writers on natural history by the title of *organic remains*; a term more properly applied to those relics in which some part of the organic matter is still traceable.

24. Those organized beings which are somewhat complex in their structure, have occasion to perform many acts which are also complex, and require the assistance of many organs acting in concert. Thus, man, in moving from place to place and performing mechanical operations, requires the use of most of his *muscles*. In examining the properties of any thing which interests him, he often has occasion to see it, feel it, taste it, &c. Now you have doubtless learned already that the senses by which we perceive the properties of things are all dependent on a class of organs called the *nerves*. I do not suppose that you have yet a clear idea of what is meant by a muscle or a nerve: these things I shall describe hereafter; but I allude to them here only to explain the meaning of another term which presently I shall have occasion to use. Any set of organs which are employed in accomplishing one common purpose is called a *system*. Thus we have the *muscular system* for motion, the *nervous system* for perception, and many others.

25. The word *system* is commonly employed in conversation to signify the whole frame or body of an organized being; and you have no doubt heard very sensible people say, when the doctor and they disagree as to what is proper for their health, "I know my own system. Every man best understands his own system." Now this is a very vague use of the term. It confuses the mind, and it is better to avoid it while engaged in studying this little volume.

26. Having now explained wherein the peculiar motions of living things, or organized beings, differ from those which are common to them and to inanimate

matter also, and having given you a few necessary definitions of terms, let us proceed to examine, in the same general and introductory manner, the differences in the mode of growth between organic and inorganic bodies.

27. To obtain a clear idea of the mode in which inorganic bodies grow, I will tell you of a pretty little experiment which you may try for yourself on a suitable occasion. Get a good large lump of alum; put it in a suitable vessel, and pour upon it some boiling water, but not enough to dissolve it all. Let it simmer before the fire for a quarter of an hour. Then pour the boiling water off into a clean oil-flask. Keep the fluid hot by placing the flask on the ashes, or over a lamp, till you have time to tie a string round a small piece of solid alum, and suspend this in the flask, near the bottom. Then set the flask in a cool place, and you will see the small piece of alum growing with rapidity as the fluid cools. And if you are careful not to let it cool too fast, you will see that the alum grows by covering itself all over with beautiful little crystals which are continually increasing in size. Even upon the string, you will often perceive other crystals which seem to grow there spontaneously. Your preceptor has no doubt explained to you, ere this, the nature of crystallization, but I wish to call your attention to the fact that all the growth of the piece of alum is produced by the deposition of more alum upon the outside of it. Not a particle has passed into the interior of the lump. Nor has there been any change produced in the nature of the lump, or the matter added to it. The lump is still alum, and all that has been added to it is no more than so much alum, which has been taken from another piece of the same substance and conveyed to this by the water. Such is the nature of growth when it takes place in any inorganic body whatever. It is true that all such bodies do not crystallize, but their growth is always the consequence of the addition of particles upon their external surface, and whatever they gain must be lost by some other portion of the same kind of mat-

ter. They never have the power of selecting different materials and converting them into particles of their own nature, so as to appropriate them to their own use.

28. Now the history of the growth of organized beings is the reverse of all this. Neither a plant nor an animal ever grows by the addition of particles applied from without upon its surface. The bark of the tree increases in thickness as the tree grows older, because every year a new layer is formed on its inner side. The external false skin or cuticle of an animal is continually wearing off; as in man; or it is regularly burst and pushed off bodily at stated intervals; as in snakes, crabs, and the silkworm, which shed their coats; yet as frequently is a new skin produced beneath that which is loosened or torn off, and this is formed of matter from the interior of the animal.

29. You see, then, that as the growth of all living things takes place within their substance, it is necessary that the materials for their growth, which are only to be found without, should enter into the interior and penetrate their substance in all directions to reach the various parts which are continually growing.

30. A tree absorbs its food from the soil. This food consists of water, in which is dissolved a variety of salts. It also absorbs certain kinds of air by its leaves, and these substances combine with each other in such a manner as *to form the sap*, which nourishes the tree. Man lives upon the bodies of other animals and plants, which he takes into his stomach. The sides of a canal connected with the stomach absorb such parts of this food as are fitted to support the frame. Man also absorbs certain kinds of air by means of his lungs in breathing, and these substances combine with each other in such a manner as *to form the blood*, which nourishes him.

31. Now, out of the same sap, the tree must form bark in one place, wood in another, its fruit in a third, &c.; and out of the same blood, the man must make skin in one place, a muscle in another, a nerve in a third, &c. Hence you perceive that organized beings possess the

power of changing other things into their own nature, and are able to construct for themselves the particles necessary for their growth.

32. In order to make so many different parts out of the same sap or the same blood, the plant or animal must possess the power of moving the nourishing fluid from place to place, wherever it may be needed ; and this fact must remove all doubts that you may have entertained as to the existence of an independent power of motion peculiar to organized beings (18) ; so that you can now comprehend with clearness the broad differences existing between *things which have life and things which have not life*.

33. Before we quit this subject entirely, however, I must explain a few apparent exceptions to the rule laid down in paragraph 27. You remember our little comparison between the sponge in a basin and the flowers in a vase (7). Both seem to grow by the same process. Now the sponge was once part of an organized being : it still contains a good deal of organic matter ; but it has been long dead, and possesses no powers but such as properly belong to inorganic matter. *Yet it seems to grow* by drinking up water, or, in other words, by receiving food into its interior, just like the flowers. I can show you, however, that it does not grow, and that the flowers do. Take your scales, and weigh first the dry sponge. Instead of the open basin used in our first experiment, take a ground stopper glass jar nearly full of water. Weigh it, and mark the height of the water in the jar very exactly, with a piece of greased charcoal. Now put in the dry sponge, and let it *seem to grow*. Next day you will find the sponge fully expanded and very large. Yet the water stands at exactly the same height that it did before, and the whole apparatus weighs just as much as the bottle, the water, and the dry sponge taken together did weigh before the experiment. You may change the water, filling the jar to the same mark every day, as long as you please, yet the weight of the whole will remain the same. Now take the sponge out of the water and dry it. You will

then find that it weighs exactly as much as it did at first. *It has not grown a particle by admitting other matter into its interior.*

34. To compare the effects of water on a sponge with those which it produces on a plant or flower—take a narrow-necked flower-vase, and fill it completely with water in the spring of the year, or in a warm room in winter; weigh it when thus full, and note the weight. Then choose the bulb of a hyacinth, of such size that it will just cover the top of the vase without falling into it, but so rounded that the bottom of the bulb will sink half an inch or more into the water. Weigh this bulb also, and note the weight. Then add the two sums together, and preserve the remembrance of the amount. Now set your bulb on the vase, with its large end in the water, and supply it daily with fresh water. You will soon see the roots growing rapidly downwards until they seem almost to fill the vase, while, in a few days, the leaves will shoot and expand from the smaller end, and at last the flower-stem with its buds will spring up, and the flowers will bloom. If you weigh the vase, together with the plant, from time to time, you will find it continually growing heavier and heavier; thus showing most plainly that the plant has converted a portion of the water (perhaps with certain salts, or other impurities, which are always found in water that has not been distilled,) into matter fitted to form part of itself, and has appropriated this matter to its own use.

35. All the cases of seeming growth by absorption which we witness in inanimate matter, resemble the case of the sponge in the foregoing experiment. Let us take the case of an iron bar, heated in a forge at the blacksmith's. You see that the hotter it becomes, the larger it grows. But this is entirely owing to the absorption of heat by the iron, as water is absorbed by the sponge. When the iron is taken out of the furnace, the heat leaks away or flies off, till it is as cool as the air around it; just as the water flows out, or evaporates, when you hang the wet sponge in a dry place.

36. You see, then, that unlike things which have not

life, all organized beings possess a power of moving to seek what they want, moving their nourishment from place to place within them to supply the growth of their different parts, and moving even their solid particles in such a manner as to make room for the other particles by which their size is gradually increased. This power resides within themselves. This power is LIFE.

37. Of the nature of *life* we know nothing. An animal dies: its body is still composed of organic matter. At the moment of death it does not undergo any change that we can discover. It only ceases to move. Yet the power residing within it has departed! Then what is this power? Every child has asked himself the question, but it has never been answered. We know it only by its effects. When an animal or plant is labouring under its last illness, (for plants can be sick as well as animals,) the effects of life grow weaker and weaker. But what becomes of life itself? Does it cease to exist when it ceases to move the body? The Scriptures tell us that the Creator, after he had completely formed man, breathed into his nostrils the breath of life. That is, he put in motion the body he had formed. Whether he still maintains that motion by his own direct influence, or whether he acts through one or many agents in producing such effects, we know not, for he has not shown us. I must beg of you to remember this through life. We never can know any thing of the first link in a chain of causes and effects, unless instructed directly by the Great First Cause of all things. By remembering this, you will escape the danger of being led astray by the thousand follies of the wise, when they attempt to lead us beyond the boundaries of human-learning—follies which I most fervently desire to escape in writing this little book for your instruction.

CHAPTER II.

ON THE INDIVIDUALITY OF ORGANIZED BEINGS, AND THE
DIFFUSION OF LIFE IN LIVING BODIES.

38. EVERY part of an organized being enjoys the privilege of life, for every part possesses the power of regulating its own motions in such a manner as to choose the particles which are required for supplying its own growth, and to place them in their proper positions. Now, all such beings as are a little complex in their structure, are composed of many organs, each of which performs a distinct office. Thus; the eye of a man is made for seeing, and the flower of a tree is designed to produce the fruit. In the ordinary course of events, the finger does not see, neither does the leaf bear fruit. These organs, therefore, require peculiar powers of life, or, as we term them, peculiar *vital powers*.

39. The appropriate acts of the several organs are called their *functions*; and when we speak of all the acts of all the organs of an animal or plant, we term them *the vital functions*. Thus it is the function of the eye to see, that of the ear to hear, that of the mouth to speak, and that of the flower to protect and foster the young fruit.*

40. Though every organ in a complex living body

* (To teachers.)—The term *vital function* is used by some eminent writers in a more restricted sense, to signify those functions only that are common to all living things, as distinguished from those deemed peculiar to animals, such as sensation and voluntary motion. So far as these latter functions are dependent on the organization, they are as purely vital as any others observed in living bodies; and as the restriction of the wider meaning of the term is calculated to lead to false impressions as to the real importance of certain parts of the animal frame, I have declined attempting it.

enjoys, as you perceive, its own peculiar mode of life, (38.) yet it does not follow that, if separated from the body, it could continue to live when thus deprived of the assistance of other organs. The stem of a tree does not flourish when deprived of its roots and left in a situation where it cannot form new ones; for, although it possesses the power of propelling the sap that causes it to grow and enables it to shoot out branches, leaves, and flowers, yet it is unable, in most cases, to keep up the supply of sap. The stem does not perform the functions of the roots. Hence you understand that, in complex plants and animals, if any important part be wanting or out of order, the whole organization suffers; or, in other words, the health of every part is necessary to the health of the whole, and no one function can be impaired without embarrassing all the functions.

41. But you are aware that all parts of a plant or animal are not equally important. For a man can very well spare an arm or a leg, and his health may not appear to be injured by the loss. It would even seem that by lopping off part of a plant we improved its vigour; for we trim our vines in the spring of the year to make them bear more grapes. When, however, you remove or divide any very important organ, the being generally dies. If you cut off a man's head or open his heart, he sinks immediately; and if you pass your knife or your axe all around the trunk of a tree, so as to divide the inner bark quite through to the wood, the tree soon withers. This is the way in which the western farmer begins to clear his land of the forest.

42. Even a small wound, or the removal of an unimportant part, would almost always kill the plant or animal, sooner or later, were it not that the vital functions of every living thing enable it to heal such injuries. For, as all that lives requires food to supply its growth and support its frame, and as this food is always converted into sap or blood, which are fluids and run out when the body is wounded, a very small cut, if allowed to remain permanently unclosed, would be sufficient to exhaust the supplies on which the continuance of life

depends. We often see this proved when the peculiar health or condition of the plant or animal prevents a wound from healing. A small cut in the bark of a grape-vine when the sap is running, in the spring of the year, will sometimes cause it to bleed to death; and there are many cases recorded by surgeons, in which man has suffered in the same way from the scratch of a pin, or the extraction of a tooth.

43. Now the power possessed by different organized beings to heal the injuries which they receive by accident, appears to be greater exactly in proportion to the simplicity of the structure of the injured being. Man is the most complex of all animals, *and if you cut him in half, both pieces will die*, but if you serve a common earth-worm in the same manner, it is said that the pieces both heal at the wound, and each piece may continue to live as a separate worm.

44. There are animals, much simpler in structure than man, that will die after their heads are cut off, but many of them, though they cannot live long enough to make themselves new heads or new tails like the earth-worm, are yet capable of moving, and performing many vital operations. You all know how long the tail of a snake will curl after it is cut from the body; but I have some still stranger stories to tell you. When the hind legs of bull-frogs have been cut off, skinned, and placed over the fire to be cooked, they not unfrequently "*hop out of the frying-pan into the fire.*" I was once dining very comfortably on some soup made from a large snapping-turtle that had been beheaded on the preceding day, but being extremely startled by the loud howling of a favourite dog in the yard, I ran out to see what was the matter. Poor Cæsar was whining piteously, and stood looking intently at one spot on the ground, with an air of extreme bewilderment. I went to examine what had "*puzzling set his puppy brains,*" when, behold! there lay the head of my snapper, with the end of the dog's nose fairly bitten off by its jaws while the poor animal had been innocently smelling after his share of the dinner.

45. A tortoise will live for a long time when deprived

of both its brain and its heart. When an unfortunate shark has fallen into the hands of its cruel enemies, the sailors, it is frequently opened and cleaned while still alive; but, although taken from its natural element and treated in this manner, it will still make formidable battle with its jaws and tail, sometimes for hours afterwards.

46. Thus, you perceive that in proportion to the simplicity of the structure of an animal, the powers of life seem to be more equally diffused through every part, and the health of the whole becomes less decidedly dependent on the health of each of the parts. Having arrived at this conclusion, you will be less astonished at what will be stated hereafter.

47. Even the fluid parts of animals and plants are said to be organized; and, from the moment at which food is taken in by the roots or the stomach, it undergoes continual changes, until the part that is fitted to nourish the body is converted into perfect sap or blood, and carried to the different organs for their sustenance. These changes bring about a continually increasing resemblance between the part of the food which is thus appropriated, and the substances of which the body and its various organs are composed; and the process by which they are accomplished has been termed *assimilation*.

48. When the assimilation of the food is completed, as far as possible by the roots, or the stomach and bowels, the fluid formed by it no longer resembles in its nature any thing that is found in the inanimate world. It constitutes a part of the living being from the moment when it is received within the body, and the actions of life cannot be maintained without its presence. There is strong reason to believe that this fluid, like all other parts of a living body, partakes of the powers of life; or, in other words, fulfils its own vital functions.

49. I shall not attempt to enlarge upon this subject in addressing young beginners in physiology; but it is necessary to mention a few facts, to show that the fluids are extremely simple in structure in the simpler animals and plants, but become much more complex in those

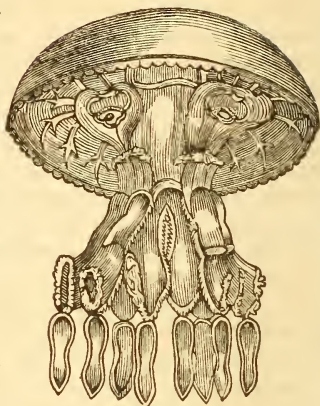
which are composed of many organs, and are destined to fulfil a large circle of usefulness. The sap of most plants is composed chiefly of water, and the proportion of other matter contained in the fluids of those which rank lowest in the scale of nature is very small; but it is much larger in many of the trees and other vegetables that produce large quantities of gum, resin, sugar, meal, and other materials useful to man. Plants, it is true, never reach that high degree of complexity in their organization, which we see in the most important animals; and, therefore, you will not be surprised to learn that the sap contains very little matter that seems to be distinctly organized, even when examined under the microscope. But in the sap of the somewhat extensive group of vegetables that pour out a milky juice when wounded, we may detect, by the aid of strong lenses, a number of distinct solid globules; and these globules, being a product of life unlike any thing existing in inanimate nature, cannot be regarded as other than organized bodies.

50. The substances which form many of the plants that have just been mentioned, bear a stronger resemblance to animal matter than those which are found in most vegetables; for they contain a peculiar kind of gas (*nitrogen*) which was formerly supposed to be confined, among living things, to animals alone. But it is not our intention to enter farther than is absolutely necessary into the consideration of the chemical structure of living things, or into the subject of vegetable physiology.

51. Now the simpler races of animals, like most vegetables, are nourished by juices composed chiefly of water, combined with a very small portion of salts and earthy matter, and although we call these juices by the general term of blood, yet they present a very different appearance from blood as it is found in the more complex animals, nor has any thing resembling the solid globules been certainly detected in all of them.

52. At fig. 2, you see the representation of a curious and very beautiful animal, of a tribe which naturalists have generally termed a *Medusa*, because most of the animals of this tribe are furnished with long snake-like tendrils, which will sting severely when they are touched. You have heard of the *phosphorescence of the sea*,—the light that is emitted by the waves of the ocean when agitated—which is often very brilliant at night. I have been able some-

Fig. 2.



Medusa.

times to read a book by this light, when sailing in the Bay of Bengal, and the South Atlantic Ocean. Animals of the tribe now under notice, are perhaps more remarkable than any others for this power of giving light; so you perceive that they are endowed with faculties capable of yielding both pleasure and pain, even to proud man himself. Yet if you draw one of these animals from the water, and lay it in the sunshine, it resembles a mere mass of jelly, in which you cannot readily detect any organs, and, in a little while, the whole mass seems to melt with the heat, and flows away like water,—leaving so little solid matter behind, that, when dry, this can scarcely be detected.

53. That the *Medusæ* are really animals, there can be no doubt, for they swim with a regular slow motion, seizing upon small fish, crabs, and other minute beings, by means of their stinging tendrils (52.) By contracting these long appendages, they contrive to throw their food into a cavity which serves them as a stomach. When you cut off a part of the body of a *Medusa*, the piece will often continue to swim, though we know not at

present whether it be capable of forming a new and perfect animal—as in the case of the earth-worm (43).

54. It appears, then, that among the least perfect of living things, not only the solids, but even the fluids, are more simple in their structure, or less distinctly organized, than they are among beings of more dignified station. And indeed this seems perfectly reasonable. The fluids are designed to furnish the materials for the growth of the solid parts,—and, therefore, when the solids are nearly or exactly alike in all parts of the body, it is obvious that much less variety of matter is requisite in the fluids.

55. It is also obvious, that when the frame of an animal contains very little solid substance; as in the Medusæ; the fluids may be in a larger proportion and more watery.

56. It will now less astonish you that the powers of life are more equally distributed through the whole frame of the simple creatures that form the lowest links in the chain of animate nature; and that portions of a certain size cut from their bodies should be so often capable of preserving their life, independently, so as to constitute distinct beings; for each portion possesses a part of every thing necessary to form the entire animal; which cannot be the case in those which are composed of many distinct systems of organs (24).

57. In fig. 3, you see a magnified representation of what is, perhaps, the simplest of all animals. It is called the *hydra viridis* by naturalists. It inhabits fresh waters, usually climbing on the under surface of the leaves of aquatic plants, and is so small that close attention is necessary to enable us to detect it with the naked eye. You observe that the body of this animal is shaped somewhat like a jug placed upside down, and adhering by its base to the surface from which it depends.

What corresponds to the mouth of the jug is surrounded by long and flexible arms, by means of which it seizes its prey

Fig. 3.



Hydra Viridis.

The body is hollow, and the cavity communicates with the arms, which are somewhat tubular, and the whole of this internal space may be considered as the stomach of the hydra. The food, which it swallows with great voracity, passes freely from the body into the arms and back again while undergoing the process of digestion; and this motion depends upon the power possessed by all parts of the animal to contract or expand themselves at will, so as to press the contents of the general cavity from place to place.

58. As it is evident that the stomach and bowels of an animal answer the same purpose in their economy that the roots do in the case of plants—namely, to select and absorb the proper nourishment for the living body—there is every reason to suppose that the whole interior surface of the hydra, including even the arms, has the power of changing the food into nourishment—a process that is called by physiologists *digestion*—which may be regarded as the first step towards *assimilation* (47).

59. There is also every reason to suppose that the nourishment, when formed, is taken into the substance of the hydra by all parts of this surface; or, in other words, that the sides of the cavity have every where the power of *absorption*; for not even the most delicate microscopes can detect any distinct passage by which the nourishment can enter, or any particular reservoir or canal, in the solid frame of the animal, for the reception or distribution of this matter.

60. You now perceive how wisely it is ordered that the food should be thrust backward and forward from the body to the arms, and from the arms to the body, so that every part of the animal may absorb the nourishment necessary for its growth and sustenance. For the hydra has not the blood-vessels, which in the more complex animals, receive the nutritive fluid, and convey it to all parts of the body,—and it is, therefore, necessary that the only great cavity should fulfil, in some degree, the double purpose of a stomach and a heart.

61. If we turn a hydra inside out, like the finger of a glove, strange as it may seem, the creature does not die.

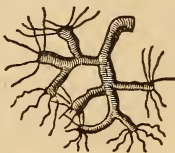
What was the external surface becomes a stomach, and *what was the stomach becomes an external surface*. Yet the animal continues to grow and prosper; proving that not only the inner, but the outer surface also is capable of digesting food and absorbing the nutritious fluid which supports the animal.

62. From what has been said of the hydra, you will naturally conclude that its organization must be extremely simple, and hence, that all parts of the animal must possess powers of life nearly equal, both in degree and kind (44); so that when divided into many parts by the knife, each part may live separately, and form itself into a perfect animal (43). This is the case to an extent so remarkable, that if the hydra be split throughout a great part of its length, each part forms a distinct animal, adhering to the remains of the original body. If the same operation be performed upon each of these branches, thus artificially produced, two more animals will be constructed in the same manner; and we know not how far the process might be carried before the life of the hydra would be destroyed. In fig. 4, you see a single specimen which has been split repeatedly in this manner, until it has formed seven hydras attached to the original body, and having a cavity or stomach common to them all.

63. Sometimes the hydra splits itself spontaneously into halves, each of which becomes an independent animal.

64. If we cut one of these simple creatures into a number of pieces in any direction, each piece will be found, in many cases, to complete itself and form a perfect hydra; but even here there is a limit to the powers of life. If the division be carried too far, or if the animal be crushed, the fragments die. We cannot powder a hydra, like a piece of lime, and yet leave every particle a hydra; because every thing that has life is organized, and if we destroy any essential part of its organization, it must cease to live.

Fig. 4.



65. In attempting to discover the real organization of the hydra, we perceive little in its substance but a mass of soft and flexible membranes formed into cells containing an animal juice, which simple fluid answers the purpose of blood, and supports the frame. The cells are so small that we cannot distinguish them by means of sight, but we infer that they exist, because the fluid does not run out, at once, when we cut the hydra open, and then subject it to light pressure. This membrane appears to be more firm in some places than in others, probably because it is thicker, and perhaps because the cells are smaller in such situations. The external surface of the animal, which we may call the skin, has more firmness than the internal parts, but with this exception, there is nothing to distinguish one portion of the body or arms from another, and it is, therefore, not so very wonderful that small pieces, when cut off from the parent animal, should continue to live.

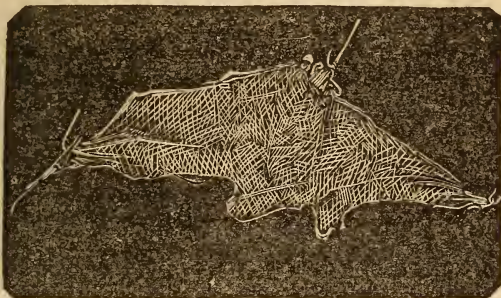
66. I must now give you two more definitions, in order to prevent the necessity of too many words in our future descriptions. The membrane of which I have been speaking is called *cellular membrane*; something analogous to it is found in the structure of every thing possessed of life.

67. In animals, the cells of this membrane are seldom perfect, but have communications with each other, permitting the fluids which they contain to flow slowly from one to another; and, in particular parts of the more perfect animals, these openings are so large and numerous, that the membrane seems to be composed of a network of irregular fibres, rather than a collection of cells. For this reason, and some others which need not be mentioned here, the membrane is often termed by physiologists the *cellular tissue*. It is important that you should remember that both the terms just defined are often employed, indiscriminately, with the same meaning.

68. The cellular membrane that appears to form the whole body of the hydra, is found in all animals in great abundance, but is differently arranged according to the particular class of animals in which it is observed. In

man, if we examine a single film of this tissue, under a strong microscope, we find that even the sides of the cells are evidently composed of very minute fibres, with intervals between them too small to allow the most searching liquid to flow readily through the tissue, but large enough to make it less wonderful that this membrane should be found capable of absorbing nourishment, and that it should slowly transmit fluids in the form of vapour, as, in the sequel, you will find that it does. The fibrous appearance just described, is well displayed in fig. 5,

Fig. 5.



Cellular membrane magnified.

which represents a film of cellular tissue, highly magnified. On increasing the power of the microscope still further, the fibres seem to be composed of rows of globules: but all observations made with instruments of such prodigious power, are very apt to produce deceptive appearances. Those of you who have ever seen an animal skinned, may have noticed that the skin is attached to the body by a white or transparent substance, which may be torn very easily in many places, but, in other situations, it requires to be cut before the skin can be detached. This is the cellular membrane or cellular tissue.

69. To show that the cells communicate with each other, it is only necessary to mention that dishonest peo-

ple, when preparing chickens or other small animals for market, not unfrequently introduce a small pipe through the skin, and blow through it into the membrane beneath. The air enters the cells, and passing from one to another all over the body, gives it the appearance of being very fat, and ignorant purchasers are not always able to detect the deception.

70. It sometimes happens that, when a man has broken one of his ribs, the air from the lungs is forced into this loose cellular tissue through a wound made by a portion of the broken bone. The body may then be swelled by the air until even the neck disappears, and the person resembles a great bladder, with nothing but some features of the face, the palms of the hands, and soles of the feet retaining their natural appearance; Yet this accident, frightful as it looks, is not necessarily dangerous. The air may be rapidly absorbed, or it may be allowed to escape through a few small incisions made in the skin by the surgeon.

71. In many parts of the larger animals we find collections of fat in the cellular tissue; and anatomists have discovered that fat is always collected into masses which, when examined carefully, resemble little bags or sacs of oily matter, bound together by the cellular membrane that surrounds them. When one of these sacs is examined under the microscope, it is found to contain a multitude of very minute hollow globules, composed of a transparent membrane, and grouped together much like a bunch of grapes. Each of these globules contains an exceedingly small drop of the oily matter that gives character to fat, so that in rendering lard or tallow, or in other words, melting it in boiling water, the oil bursts the globules, and rises to the surface of the water. Without the aid of heat or strong pressure, the oil cannot escape. Now we are unable to discover any communication between these globules, such as is found between the cells of the common cellular tissue; and hence, modern physiologists have generally believed these bundles of globules to be formed of a peculiar mem-

brane which they term *the adipose tissue*. But cellular membrane in many places is found to be impervious to air or any other substance which we attempt to introduce artificially; as I shall have occasion to mention hereafter; and we have not yet discovered any material difference in other respects between the latter and the adipose tissue. It is quite as consistent with the probable truth, to regard the globules containing the oily matter of fat as closed or complete cells of cellular membrane. The appearance of adipose tissue, so called, is seen in fig. 6.

Fig. 6.



Adipose Tissue.

72. Of cellular tissue, then, the whole body of the hydra is composed, though, from its granular appearance, it probably contains something analogous to fat in various parts of its substance. It seems to possess no particular organs, properly so called, for although the skin is a little firmer than the other parts, yet its substance is apparently precisely the same, and although the arms of the animal are used for seizing its prey, yet when one of them is cut off, it almost immediately becomes a perfect animal; and it is most curious to observe how fully a creature so extremely simple can perform the different functions which, in more complex beings, require as many different systems of organs for their accomplishment.

73. As there is no difference between its inner and outer surface (61), it is obvious that it can carry on *digestion* (58) and *absorption* (59) by means of its skin.

74. As the hydra dies, like all other animals, when entirely deprived of air, and as it has no particular organ, like those of a fish or any other aquatic animal, for breathing the air-bubbles combined with the water in which it is suspended, it is obvious that it *breathes* by its skin.

75. It owes its form entirely to the elasticity of the cellular membrane, and it can only change that form by contracting one portion of the membrane while it allows another to remain relaxed. Yet it walks slowly

along the stem or the leaf of a plant, by arching its body and applying its mouth and tail alternately to the surface.

76. The involuntary motions that drive the food from the stomach into the arms, and back again (57), and agitate the nutritive fluid or blood, from cell to cell, throughout its substance, so as to nourish every part of its frame without the aid of blood-vessels, are not its most remarkable functions; for it shrinks when touched or disturbed; so as to give plain evidences of *consciousness*, although no human skill can detect the slightest trace of a nerve in its organization.

77. Without any visible muscles, it can wrap its long arms around an active little insect or worm; and so voracious is it, that when two hydræ happen to seize upon opposite ends of the same prey, each swallows his own portion, until their mouths come together; when the larger of the two has been known not only to gorge the whole of the prey, but with it the body of his antagonist also. The result of the contest forms a curious exception to the truth of the old adage, that "*the weakest goes to the wall*;" for it so happens that the smaller hydra, while in the stomach of the larger one, leisurely devours and digests the whole of the prey, but being himself *rather indigestible*, he is ultimately ejected, the happier for having lost the battle. Fig. 7. represents a contest of this kind.



Combat of Hydræ.

78. You have now obtained a tolerably clear idea of the difference between organized beings and inorganic matter; and you have also a clear conception of the simplest organization which is consistent with animal life. In the order usually observed by writers on physiology, I should now proceed to point out the distinctions between animals and vegetables. But if we begin with the beginning of these two scales of living things, as we should do when teaching the first principles of the science, the establishment of a clear distinction is by no means an easy undertaking. The simplest forms

of vegetable and animal life resemble each other so very nearly, that no perfectly satisfactory definition of the difference has ever been given; and even between a forest tree and the bird that builds in its branches or the squirrel that subsists upon its nuts, there are more points of resemblance, so far as the vital functions are concerned, than you would be able to comprehend, were I to attempt to explain them at present. For my own part, being unable to discover any positively certain distinction between the two great kingdoms of animated nature in the peculiarities of their organization, I have arrived at the conclusion that *consciousness* and *will*—faculties that appear to be exclusively possessed by animals—form the only marks which can, in every case, distinguish them from vegetables, and these being functions of the mind, are beyond the reach of physiology, which treats only of those of the organization (39, *and note*).

CHAPTER III.

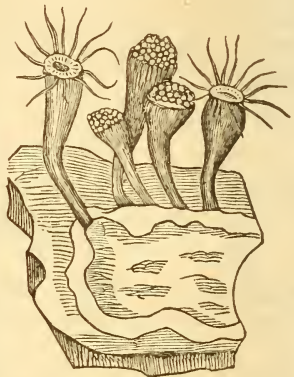
ON THE ORGANIZATION AND FUNCTIONS OF ANIMALS SO SIMPLE AS TO BE APPARENTLY DIVESTED OF SPECIAL ORGANS.

79. IN the last chapter you learned that an animal may exist with a frame so simple that we can detect nothing in its structure but simple cellular tissue, and yet may seek, catch, and digest its food, grow, feel, and execute its will, without the aid of any particular organs. But it must be evident to you that such soft and delicate beings are altogether unable to protect themselves against powerful enemies, unless they escape observation by their minuteness. Most of these creatures are therefore exceedingly small.

80. The very weight of their own bodies would prevent them from easily preserving their shape and per-

forming their necessary functions in a fluid as light as air; and they are therefore seen to inhabit the water only.

81. Some of the smallest known animals are destined by nature to remain fixed in one spot from near the time of their birth. These cannot go in search of their prey, and would therefore starve if nature had furnished them with no means of bringing their prey within their reach. At fig. 8. you see a specimen of a polypus; but not the somewhat dangerous marine animal of that name, of which are told so many wonderful stories, either true or fabulous, and which is more properly called the cuttle-fish. This little animal belongs to the same general class of minute beings with the *hydra viridis*, (fig. 3,) and that which forms and inhabits the various kinds of coral. The particular species here represented is a *zoanthus*. It is permanently adherent to the rock on which it grows; and though it can elongate and contract its body, and employ its numerous arms, or *tentacula*, as they are called, like the hydra, yet it would be difficult for it to obtain food without some other contrivance for bringing its prey within its reach.

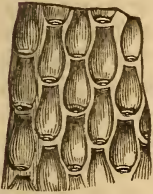


Zoanthus.

82. This is effected, in nearly all the polypi, by certain little fibres, like hairs, placed in various orders around the mouth. These hair-like organs, which are called *cilia*, are continually in motion during life, and produce currents in the water, sweeping towards the mouth of the animal; so as to bring any particle of food which may happen to float near the polypus, within reach of its tentaculæ.

83. The cilia of the polypi are so minute, that they are altogether invisible to the naked eye; but in fig. 9 you see a highly magnified view of the cells of the *flustra carbacea*, a very minute species of coral, that grows on the surface of marine stones, shells, or plants.

Fig. 9.



Cells of a Flustra.

Fig. 10.



Flustra Magnified.

Fig. 11.

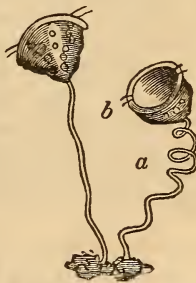


Cilia of Flustra.

Fig. 10 represents one of the animals greatly enlarged, and you observe the arrangement of its numerous tentacula around the mouth. In fig. 11 you have a single tentaculum, separately magnified, showing the cilia ranged in a row along its sides, and the arrows marking the direction of the currents of water produced by their perpetual vibration.

84. In those polypi which are not fixed permanently to one spot, the cilia become organs of locomotion, and instead of moving the water toward the animal, they move the animal toward the water. In fig. 12 I present you with the likeness of a little microscopic animal, generally considered as a polypus, but it has cilia only, without tentacula. Its body is a bell, placed on a long foot stock, that is contracted or elongated at pleasure by the animal; and by the

Fig. 12.



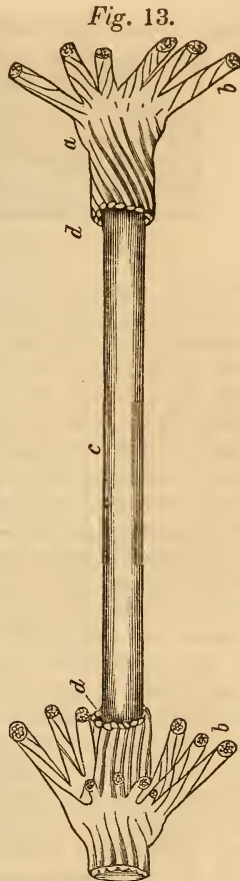
Vorticella.

base of this foot-stalk it adheres to any surface, when it chooses to do so. When *attached*, this animal—the *vorticella cyathina* of naturalists—pursues its prey by suddenly elongating its pedicle, *a*, but instantly retreats when in danger. When *detached*, the cilia, *b*, cause it to move and whirl through the water in a most curious manner.

85. We know very well how the motion of the bodies, foot stalks, and tentacula of polypi may be produced by the contractile power of the cellular tissue of which they are composed. For this *contractility*, as it is technically called by physiologists, may shorten any one part, or render it smaller, by forcing the fluids from the cells of that part into those of any other portion of the body or its appendages; which will, necessarily, render these latter larger or longer. But we can form no idea of the cause that produces the constant motion of the cilia. We have every reason to believe that this motion is not muscular, like that which effects locomotion in more complex animals; for, when a piece of the animal on which several cilia are based is cut off from the body, the cilia continue in action unchecked while life remains, and keep the fragment in motion, as though it were a distinct animal.

86. Even in aquatic beings of much more complex structure than the polypi,—beings that have a heart, blood-vessels, breathing organs, muscles for voluntary motion, nerves, &c.—we still find cilia, apparently moving in the same manner, and capable of carrying fragments about when detached from the body; though in these animals the cilia are not designed to supply food, and are usually placed about the breathing organs instead of the mouth. The common fresh water muscle displays a beautiful arrangement of this kind on the edges of its breathing organs,—where it keeps the water constantly in motion, for purposes which you will understand hereafter.

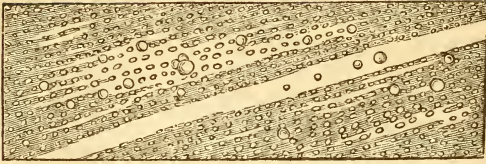
87. Even among plants, the existence of something of the same kind is inferred. Fig. 13 represents a single joint of a peculiar water plant, like a grass, called by botanists the *chara hispida*, in great degree deprived of its bark, so as to allow the observer to perceive, under the microscope, the singular circulation of the sap, which is continually going on in the hollow of each joint of the transparent stem. In fig. 14, you see a portion of a joint highly magnified; the current of sap in the cavity is perpetually passing downward on one side of the stem, and upwards on the other side. The white line marks an intermediate space between opposing currents, where the sap remains nearly at rest. Now you observe a great many regular and somewhat spiral lines of little globules in this figure. These are small green bodies, seemingly connected together by long spiral fibres, such as are often found in the inner surface of the cells of vegetables. These fibres pursue the same direction with the current of the circulating sap, and if any one of them be broken, it instantly twists itself about in the middle of the tube, "like a thing of life," and arrests the circulation. If a single globule happens to become detached, it immediately whirls round and conducts itself much in the same manner with those minute ani-



Stem of the Chara.

a, The outside bark. *b, b*, The branches shooting from the ends of each joint. *c*, The stem with the outer bark removed, and prepared for seeing the circulation. *d, d*, The outer bark of the plant.

Fig. 14.



A portion of the stem of the Chara, highly magnified.

imals that are furnished with cilia (84), and we have every reason to believe that the cause of motion is the same in both. The larger rings in the figure represent moats floating with the sap.

88. The polypi not only resemble plants in their external appearance, after the manner of the zoanthus or animal flower (81), but they even multiply by buds, like a tree. These buds are called *gemmules*. They soon fall off, and commence an independent existence. They are provided, from the first, with moving cilia, which carry them off in search of a proper place of permanent residence, the moment they are detached from the parent. In fig. 15, you see a figure of the gemmule of a flustra, covered with its cilia. Even those polypi which remain fixed for life in one spot, have thus the power of transporting their race to a distance, by means of a locomotive power which the young lose for ever the moment that they select their station: but they make this selection voluntarily and with judgment, though the motion of the cilia is constant, and seemingly involuntary in many of them.

Fig. 15.



Gemmule of Flustra.

89. By far the majority of the various kinds of polypi live together in extensive societies, of which the numbers defy calculation. The different members of each group remain connected together, in such a manner that the whole community forms one living mass, and each polypus, instead of being a distinct and separate animal, resembles one of the divisions of the original hydra represented at fig. 4 (62).

90. Now such vast communities composed of such soft materials, could not possibly preserve themselves from destruction without some solid support. Providence has, therefore, bestowed upon them the power to form for themselves cells or stems of lime or horny matter, in which their soft flesh may be encased, or over which it may be spread.

91. Sometimes this support is a jointed tube, branching beautifully like a tree, with openings in the side of each joint, through which the mouth and tentacula of a polypus peep forth, and expand themselves like a flower; as in the sertularia. Fig. 16.

92. Sometimes the support consists of round cells placed side by side, like the barrels of an organ; as you see in the tubipora, a kind of coral. Fig. 17.

93. When the flesh of the community is spread over the surface, instead of being enclosed within the support, the bodies of the individual polypi are often enclosed in cells formed in the flesh, from

Fig. 16.



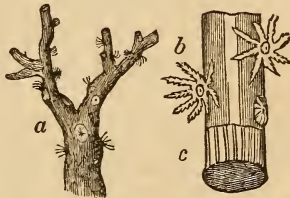
Sertularia.

Fig. 17.



Tubipora.

Fig. 18.



Precious Coral.

a, A portion of the stem with its polypi, of the natural size. *b*, A magnified portion of the stem with its fleshy covering and polypi. *c*, A portion of the fluted solid axis with the fleshy matter removed.

which cells they project themselves in search of food. The solid axis often bears the strongest resemblance to a plant with leaves or flowers. Sometimes it is com-

posed chiefly of lime; as in the common or precious red coral, fig. 18, where *a* represents a stem of the natural size, *b*, a portion with three of the polypi, one contracted, the other two expanded, and the whole highly magnified. In other species the axis is horny; as in the gorgonia—fig. 19, which represents a portion of the gorgonia briarius with a section of the flesh, showing the axis, the cells, and some of the individual polypi within them, also greatly magnified.

94. In many kinds of coral, called madrepores, the solid support of the community of polypi is as massive and almost as firm as a limestone rock, and the hard cells merely indent the surface of the rock, which continues growing with rapidity; the old cells being obliterated and new ones formed as one generation of these little architects succeeds another.

95. You have heard, no doubt, that in tropical seas the coral rocks grow with such rapidity that vessels are frequently wrecked upon them, where a few years before the soundings were very deep; and that new islands are continually appearing where once the largest vessels might navigate in safety. Yet all this growth of seeming rock is produced by an exudation from the bodies of countless millions of little animals, composed nearly, if not entirely, of simple cellular membrane, without any distinct organs except the cilia, of the true nature of which we as yet know nothing.

96. You may now be able to comprehend what is meant by *secretion*—a term applied by physiologists to that process by which a living body separates from the fluids which nourish it any substance which is required for a definite use, or which it is desirable to remove from the body. The rocky base or branching stems of corals and gorgonia are secretions from the substance of the polypus, as the outer skin or cuticle of a man—that which we see raised by a blister—is secreted by the surface of the membrane beneath it. If the cuticle be rubbed off a man's hand, a new one is almost imme-

Fig. 19.



Gorgonia magnified.

diately formed, and if the hard cell of a polypus be broken, it is rapidly repaired. The power of secreting lime or horny matter is not confined to the surface of the polypus, but is as general as its other functions; for we often find grains of the same material scattered through the substance of the flesh.

97. This power is one inherent in animal cellular tissue, the material of which the true skin and much of the solid bulk of all animals is composed. Finding it thus exemplified on the very confines of animal life, we are less surprised at its effects in more complicated beings, where we observe it clothing the shell-fish with their thousand elegant coverings, the insects with hard and jointed shells serving them as a kind of external skeleton, the reptiles with scales that are sometimes used as a house to live in (*tortoises*), and sometimes in place of feet for crawling (*snakes*).

98. The hair, claws, horns, nails, teeth, &c., of the more perfect animals and man, are all produced by the action of a similar power, and consist of horny or calcareous matter, according to the purpose for which they are designed. As if to prove that all parts of the body are capable of forming substances of this nature, the history of disease furnishes us with many examples of the irregular deposit of bony or horny matter, in the substance of all the organs of the human body. The most common affections of this character are called *ossifications*, and these have been found in the muscles, the blood-vessels, the heart, liver, brain, &c. Sometimes large incrustations of bone have been formed on the surface of the skin, where they have grown and fallen off, time after time, without producing any sore, or leaving any mark behind them.

99. As you advance in the study of physiology, you will discover that, as the complexity of the organization of animals increases, the number of secretions, or matters separated from the general mass of the fluids, becomes greater and greater, until it almost defies calculation. Very many of these substances are deposited in the interior of the animals, to form and support the several different organs; as the bones, the muscles, the

brain, &c. The secretion of such substances is termed *nutrition*.

100. Another class of secretions, more commonly so called, which we see in the higher orders of animals, are of a fluid character, and are designed, not to assist in the formation or growth of the frame, but to answer some useful purpose in the performance of the vital functions. The bile, for instance, seems to be a natural purgative secreted by the liver; and the tears, which are secreted by two little organs situated within the orbits of the eyes, are intended to prevent them from being injured by the friction of the eyelids.

101. The functions of assimilation (47, 48), nutrition (99), and secretion (96),—or, in other words, those which are connected with the growth and sustenance of the frame of a living being,—are common to all organized beings, whether plants or animals; and have been called *the functions of organic life*, to distinguish them from sensation and voluntary motion, which, being peculiar to animals, have been termed *the functions of animal life*.

102. I will close the present chapter with some definitions and illustrations of a few terms which it is necessary that you should understand before we enter upon the study of the organization of more complex animals; a study that I hope will prove more entertaining than these preliminary but indispensable remarks.

103. You have been told that the power by which the cellular tissue that forms the bodies of polypi forces its fluids from cell to cell, so as to change its form and enable it to move its arms, &c., is called by physiologists *contractility* (85). The same power is employed in pushing the fluids or blood from place to place, in order to nourish all parts of the frame (32). This motion is so gentle and slow, however, in the minute beings of which we have been speaking, that it cannot be perceived by the eye.

104. Now this contractility is a peculiar property of living things, and differs entirely from that power of contraction often observed, in consequence of cohesive attraction, in things which have not life. It has nothing in common with the cause that makes a globule of

quicksilver assume a rounded form when laid upon a china plate, or draws back and shortens a piece of molasses candy, after being stretched. It displays itself in plants as well as animals,—in every thing that is *organized* (20)—and is therefore a property or function of organic life (101).

105. In plants, this contractility rarely produces very sudden and obvious motions, though there can be no doubt that it is interested in moving the sap, as it moves the fluids of a polypus. In the sensitive plant, however, in the *hedysarum gyrans*,—a shrub that keeps its branches continually rising and falling almost with the regularity of the pendulum,—and in the tube of the *chara hispida* (87), we see much more striking results of this property. But even these remarkable examples are trifling in comparison with many that we observe in the animal kingdom. In illustration of this fact I will give you a description of the *Portuguese man-of-war*, a most beautiful marine animal called by naturalists a *physalia*. Fig. 20.

106. This little creature somewhat resembles one or more groups of hydræ deprived of their arms, *d, d*, and suspended from the under surface of a large bladder, *a*, composed of very transparent cellular membrane and distended with air. This bladder is called the body

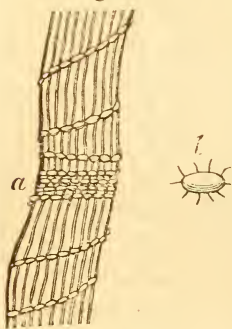
Fig. 20.



Physalia Megalista.

of the animal. At one extremity, it is occasionally curved so elegantly as to resemble the neck of a swan. It floats upon the surface of the sea and is surmounted by a membranous sail, which, as you see in the figure, is full of cavities, ranged side by side, like the fingers of a glove, *b*. From the middle of each group of jug-shaped appendages, *d, d*, which seem to be so many separate stomachs, you may observe a number of slender organs depending, by which the physalia seizes its prey. The sailors call the largest of these, *c, c*, the cable, and naturalists term them *tentacula*—a name given to a great variety of organs designed for a similar purpose in the lower orders of animals (81). When fully extended, in a physalia six inches long, this cable may measure five or six yards. The upper part of the sail is of the most splendid carmine colour; the back of the bladder, of ultramarine blue; the intermediate space is shaded elegantly through every tint of purple, and the whole surface is iridescent in oblique lights. When you recollect that the substance of the animal on which nature has impressed such glorious hues is more transparent than the palest amber, you will be able to form some conception of the exquisite beauty of the little being that looks so humble in the figure;—a beauty that I could as readily describe, as a painter could reduce to canvass the ever-changing features of a sunset sky.

Fig. 21.



Cable of Physalia.

107. The colour of the groups of stomachs is blue, and the cables, or tentacula, are generally of the same hue; but sometimes they are carmine. In fig. 21 you have a plan of a portion of the cable, very highly magnified, and at *a* you observe that the general form of the organ is cylindrical. It is studded with numerous little bead-like bodies ranged round it in a spiral line, and each of these beads is covered with minute and hard spines, of which we know not the nature. One of them is repre-

sented at *b*. Their spines are so sharp as to enter the hardest wood; and when the cable accidentally touches the wood work of the vessel, as the naturalist lifts the animal over the rail in the little gauze dip-net used for catching it, the cable is generally broken before it can be detached. The moment that a small fish, crab, or other marine animal comes in contact with the organ, it is disabled by the wounds received from the prickles, which are supposed to infuse a poison. The pain induced when the cable touches the skin of a man is very severe, and lasts sometimes for twenty-four hours, though it has been much exaggerated by travellers. The medusæ (fig. 2), and many other soft or gelatinous marine creatures, have similar organs. It is not improbable that the prickles are hollow, and seated upon poison sacs, like the venomous teeth of the rattlesnake, and the spines of nettles.

108. Now, when the physalia wishes to spread its sail, it excites the contractility of the air sac, and forces the air into the finger-like cavities already noticed. Then, by using one end of its body as a kind of rudder, it can sail not only before the wind, but obliquely, in the manner that seamen term *sailing on a wind*.

109. The moment the prickles on the cable have secured any prey, the organ contracts so strongly that it measures scarcely more than as many inches as it previously measured yards. The little beads are brought into contact with each other (fig. 21, *a*), and the prey lies within reach of the bottle-shaped stomachs, by one or other of which it is swallowed. This is perhaps the most remarkable instance of vital contractility with which nature presents us.

110. It will be evident to you, on a little reflection, that this vital contractility, which produces either perceptible or imperceptible motions in various parts of the animal frame, is not necessarily dependent upon consciousness and will. For no one dreams that a plant can *feel* the sap flowing through it, any more than a man can feel the blood circulating through his veins: nor is it more difficult to believe that without sensation, the cable of the Portuguese man-of-war may contract the moment that it strikes its prey, than it is to comprehend

how a whole branch of a sensitive plant should shrink the instant that we rudely touch one of its leaves, though it will not do so when shaken by the breeze. If, then, I have said that even the simplest animals seem to give evidence of *will* in many of their motions (17), it is not because their frame or their organs possess such powers of contraction as have been described, but because they all perform occasional motions like those of the hydra in walking, which are obviously voluntary.

111. Now almost every part of the most perfect animals, including man, displays contractility of some kind; and yet but few of these parts are gifted with feeling, and very many of their motions are altogether independent of the will.

112. Contractility, then, is a power resident in all organized bodies; but it produces no motion until it is *excited* by some internal or external cause. In the case of the cable of the Portuguese man-of-war, we see it excited by the contact of a fish or some other small animal; and here the cause is sufficiently obvious. When the air bladder of this little creature contracts in order to expand the sail (108), the organ is obviously excited by the *will*; and here the cause is much more obscure. The stomach of the polypus, like that of more perfect animals, is excited into action by the food; and the direction of the motion is determined sometimes by the quality of the food, and sometimes by the changes which it has undergone during digestion. Hence, it drives the nourishment from its general cavity into the arms and back again, and also ejects altogether any injurious or indigestible matter that may have been swallowed accidentally; as when its voracity has induced it to swallow another polypus (77).

113. Any cause which excites a part to contract is called a *stimulant* to that part. Thus, in man, the will, through the medium of certain nerves, stimulates the voluntary muscles, one after another, so as to cause him to walk or strike a blow. The flow of blood into the heart stimulates that organ, and causes it to urge forward the circulation.

114. There is a kind of contractility observable in all

living bodies, which is always excited while life remains, though it acts more powerfully at certain times and in certain conditions of the body. I mean that power which causes all parts to compress their contents with a certain degree of firmness. If it were not for this kind of contractility, the polypi and other soft animals could not preserve their forms; for a simple cellular membrane, capable of being greatly stretched by distention, and filled with nothing but fluids, could have no stability if it did not at all times press upon its contents. That it does so in all animals is easily proved, but I will present you with only a few examples drawn from the natural history of man.

115. If you pull your finger with some force, as though you designed to draw it from the hand, you perceive that you can very readily separate the surfaces of the bones at the joints to a certain distance; but the moment you let go your hold, the finger is drawn back, even against your will. This shows that the muscles are always in such a state of active contraction. The same thing is seen in the face; for however it may be distorted by passion, when the mind becomes calm the habitual expression returns without any effort of the will. This kind of contractility is called *tonicity*, and the force with which it contracts is called its *tone*.

116. You cannot separate the surfaces of a large joint, like the shoulder, without using considerable exertion; because the powerful tone of the large muscles which surround it draws the bones together with great force. But sometimes an accident, such as a severe blow or an attack of palsy, destroys the tone of these muscles; and then the mere weight of the arm will sometimes draw the head of the shoulder-bone entirely away from its socket. You all know how different is the expression of the limbs and face of a sleeping or fainting person, and that of the same individual when at rest, but awake. This difference results from the fact that, during the fainting and sleeping conditions the tonicities of all animal bodies is much diminished.

117. The same evidences of tonicities are observed in the skin, though in a much less marked degree. Cold

weather increases the tone of the skin, while heat diminishes it; hence we see that all parts of the body look comparatively firm in winter and relaxed in summer.

118. In young persons who have been rendered thin by severe illness, the skin seems relaxed, and hangs loosely over certain parts of the body; but when the health improves, the skin contracts so rapidly that long before the patient has "recovered his flesh," as we *commonly but not very properly say*, it appears as firm and as tight as ever. This is an evidence of *tonic contraction, tone, or tonicity*, and you will find, as you advance in this little volume, that tonic contraction plays a very important part in the economy of health. Were it not for this kind of contraction in the half-emptied blood-vessels, a person who had once fainted would never recover; for the heart cannot carry on the circulation of the blood in vessels that no longer contract upon their contents (113). I introduce this illustration to show that the subjects on which we are now conversing are not so unimportant to man and his interests as they may at first appear to you. The power of the heart and the nature of the circulation you will understand much better hereafter.

119. Whether the several forms of contractility which have been described may not all be the result of the same general cause, is, perhaps, doubtful; but by many physiologists they have been regarded as distinct properties. There are also other forms of contractility displayed by the muscles; but these you are not yet prepared to comprehend.

120. Having now given you some idea of the structure of the simplest animals, the manner in which they are supplied with the materials necessary for their growth and support by digestion, the mode in which they often supply themselves with a solid support by secretion, and the nature of the vital forces by means of which they preserve their form, move from place to place, seize their prey, and urge the nutritive fluids throughout their structure so as to nourish all parts of their frame, it is time to close this chapter.

CHAPTER IV.

ON THE NECESSITY FOR MASTICATORY AND DIGESTIVE
APPARATUS IN COMPLEX ANIMALS.

121. Most of the animals of which we have been speaking are so extremely simple, and at the same time so minute, that they require but slender protection, and hardly stand in need of any distinct organs for the performance of their proper functions. A single cavity, lined by what seems to be merely a continuation of their skin, suffices to receive and digest their food. All parts of their bodies lie so near this cavity that each portion is nourished by absorbing the digested fluids directly from the stomach. It does not appear that any particular organ of taste or smell is required to enable them to distinguish what food is proper or injurious for them, but they take what the beneficence of Providence sends them, without asking questions. They do not chew their food, and hence require no solid parts like teeth or jaws. We shall soon perceive, however, that much more complex apparatus is employed by animals a little more elevated in the scale of creation.

122. In many of the medusæ (52) the thickness and bulk of the body or cap of the animal is so great that it cannot be conveniently nourished by absorption from a simple central cavity; and in these animals we find the cavity which answers the purpose of a stomach divided into four principal sacs in the form of a cross, the corners of which are extended into tubes that penetrate the substance of the body, ramifying continually as they go, the smaller branches opening into each other, so as to form at last a complete net-work of canals,

through which the sea-water, together with the digested food which it contains, may be driven about from place to place for the support of all parts of the frame. In fig. 22 you see a portion of the edge of the medusa represented at fig. 2. The irregular white lines represent the ramifications of the stomach.

Fig. 22.



Edge of Medusa.

123. You have been told that the central cavity of the hydra (60) seems to fulfil the double purpose of a heart and a stomach; but in the medusa this is much more obvious.

124. In all the simple animals of which we have been speaking, the functions of digestion (58) and assimilation (47) appear to require no complex apparatus; for their food is taken into the stomach without previous preparation, and with very little, if any, selection, and the ordinary contractility of cellular tissue is sufficient to effect all the slow and gentle motions which are required for their slender purposes. But, on the contrary, in those creatures which are designed by Providence for a more extensive range of usefulness, the purposes of life being more numerous and important, the organization is proportionably more various and complicated. The food, in such beings, requires preparation before it is admitted into the stomach. If it be solid, as is most frequently the case, it must be broken down by some suitable machinery before it can be swallowed. This process requires the presence of certain firm and hard organs to crush the food. Hence; the solid jaws and teeth which we observe in all the larger animals and man;—in whom the process by which the food is crushed and prepared for being swallowed is termed *mastication*, and the set of organs by which it is effected is called the *masticatory apparatus*.

125. Even the solid teeth, which are found to compose part of the masticatory apparatus of nearly all the larger animals, appear much earlier than you would suppose among the lower orders of creation. They are

found around the mouth of the sea-egg, a little animal, the crust or shell of which you may see in almost any museum, public or private. The jaws of the common caterpillar you may observe at any time during the summer, while the little animal is engaged in gnawing the edge of a leaf. Its jaws are horny like those of all insects, and not bony or composed of lime.

126. The masticatory organs of animals are not always confined to the neighbourhood of the mouth; for in the lobster we find, in addition to very complex jaws, a set of teeth within the stomach itself, which enables this singular being to chew its food even after it has been swallowed. Many of the sea shell-fish have a long and solid tongue covered with rough ridges and spines that give them some powers of mastication. Not a few of them have horny organs in the interior which are much more powerful. There is a singular set of organs of this character near the stomach of a little shell-fish, lately brought from the coast of California by Mr. Nuttal, the celebrated naturalist. In general form this shell looks, to common eyes, very much like some of our common fresh-water snails, and like them it lives upon the edge of the water, breathing the air. It feeds upon coral, which it swallows in fragments with the animal adhering to it. The masticatory organs are found at a considerable distance from the mouth and near the principal stomach of this little animal. They resemble three rasps bound together by circular fibres, and occupy the whole of the passage for the food, so that nothing can reach the stomach without passing between them. Now, the small portions of coral swallowed by this shell-fish are so ground and broken by these files that not only is the animal matter or food torn off from them, but the very stems of hard lime on which the polypi of coral grow, are formed into little rounded pebbles which fill the intestines below the stomach.

127. The passage through which the food is conveyed, in all animals that have such a passage, (for you see that the Portuguese man-of-war has not,) is called the *alimentary canal*.

128. The organs which masticate food after it has passed fairly into the alimentary canal, are generally called *gizzards*, and this name has been given to the apparatus just described ; something similar to which is found in many shell-fish.

129. Gizzards, or internal masticatory organs, are found chiefly in those animals which have no jaws ; as in the shell-fish ; and in those whose jaws are too weak to crush their proper food ; such as birds which live upon hard grains, after the manner of the common fowl, the turkey, &c. In birds, the gizzard is not provided with any thing resembling teeth, being composed of a very firm flesh, lined with a hard, horny matter, and possessing so great a degree of contractile power that the gizzard of a turkey has been known to break to pieces a steel needle without being at all injured thereby. The domestic fowls are in the habit of swallowing hard pebbles, and these supply the place of teeth in assisting them to grind their food. When deprived of pebbles, they never continue healthy, and are apt to die of indigestion.

130. You can very readily understand that the more nearly the food of an animal approaches in its nature to the substance of the animal that subsists upon it, the easier it is for the *digestive apparatus* to act upon it ; and you will naturally infer that when the process of assimilation is simple, the alimentary canal will be proportionably simple. Such is the fact. In those animals that live upon meats, or are carnivorous, the alimentary canal is usually short and straight ; its most essential portion, the stomach, is not complicated, and digestion is rapid. But, on the contrary, in those animals that feed on vegetables,—which, though composed of organized matter, differ very widely in their organization from the animal frame,—the labour of digestion is much greater, and the digestive apparatus more involved.

131. To obtain some idea of the very complex character of the digestive apparatus observed even in animals which you may consider insignificant, you have only to examine fig. 23, which represents the alimentary canal of the common limpit, a little shell-fish adhering to rocks on the sea-coast. M represents the mouth of this animal; T is the tongue; S the stomach, and O the intestine wound round and folded upon itself so as to occupy but little space.

132. Now, in many fishes and birds of prey, the alimentary canal passes almost directly through the body, and the stomach is but a slight enlargement of the canal, while many other animals not only have much more complicated intestines, but are provided with other enlargements of the canal besides the stomach, such as the craw or crop in pigeons and fowls. All beasts that chew the cud, or ruminates, such as the ox and the sheep, have four stomachs in the place of one, and each of them has its own peculiar duty to perform in effecting the digestion of the food. The first of them, for instance, receives the food when it is taken, and retains it for some time, until the animal is at leisure to chew it more deliberately. It is then passed into the second stomach to be there moulded and thrown up in small parcels into the mouth again to be fully masticated; after which it descends into the following stomachs, which continue the process of assimilation. Connected with the alimentary canal of the camel we find receptacles for containing pure water, which enable this animal to traverse the wide and arid deserts of Africa, where water cannot be had. The traveller in these deserts is often preserved from death, by thirst, in consequence of the supply of water obtained by killing one of his camels.

Fig. 23.



Alimentary canal of a limpit.

CHAPTER V.

ON THE NECESSITY FOR A SPECIAL APPARATUS OF MOTION—
THE MUSCULAR AND OSSEOUS SYSTEMS AND THEIR APPEN-
DAGES.

133. By this time you must perceive, very plainly, that the motions, both internal and external, performed by animals of much more elevated rank than the polypi, are far more numerous and powerful than theirs. The force required to break down the solid food on which many of them subsist, by means of firm organs, such as teeth, jaws, or gizzards, is much greater than the soft and delicate cellular tissue of an animal could exert. Such beings, therefore, require, and are consequently provided with, a separate system of contractile organs, called *the muscular system*. The *muscles* which compose this system display prodigious powers of contractility and, when called into action, they draw together the parts to which they are attached with a strength that is altogether astonishing, when we consider their softness and apparent tenderness. Thus a strong man can rise upon his toes while lifting a weight that requires the muscles of the calf of the leg to exert the force of a ton and a half. Yet so completely is this strength dependent upon the principle of life, that, immediately after death, a small portion of the force just mentioned is sufficient to tear the organs to tatters.

134. The muscular system, then, is the apparatus by means of which the more perfect animals perform all motions that are very prompt, and all those that require much force. The limbs and body are provided with muscles to enable them to perform all their mechanical actions; the alimentary canal is also surrounded with muscles to propel the food from place to place, as the

progress of digestion requires such changes, &c. But, these motions, being extensive and performed only when occasion requires them, seem to be dependent on a totally different kind of stimulation from the *tonicity* that the muscles display at all times, in common with most other parts of the body, (114, 115). You should, therefore, avoid confusing the more active muscular contraction, which appears to be the result of the action of peculiar stimuli upon these organs, with the tone of the muscles, which is the result of causes producing the same constant contraction of all other parts.

135. As some of the motions of a complex animal, such as those which are designed to carry him about in search of food, or to masticate that food when found, require to be under the government of the will, the muscles which perform these motions are called *the muscles of voluntary motion*.

136. But the motion of the food during digestion and those other operations upon which the growth and nutrition of the body depend, could not be trusted with safety to the control of the will, lest the passions, the follies, or the indiscretions of the animal should be continually arresting or embarrassing those operations, thus destroying all security for the continued health, and perhaps the life of the individual. Providence has therefore wisely ordered that the muscles upon which these motions depend shall act under the impression of their proper stimulants, without the control or the consciousness of the animal. They are, therefore, called *the involuntary muscles*.

137. The acts which are performed by the involuntary muscles are such as are necessary to the functions of assimilation and nutrition, the digestion of food, the absorption and circulation of the nutritive fluids, the growth and the support of the organs. Now these vital functions are common to all organized beings; they are functions of organic life (101); and hence the muscles of which we are now speaking are called *the muscles of organic life*—while the voluntary muscles, which do not

directly contribute to the same processes, but to others which are peculiar to animals, are called also *the muscles of animal life*.

138. There are certain operations directly connected with organic life that cannot be safely entrusted to the absolute government of the will, on the one hand, nor entirely removed from its control on the other. Thus life cannot be supported for more than a few minutes without breathing, but it would be impossible to carry on the ordinary business of life if man were compelled to breathe at all times, or at perfectly regular intervals. Again: If obliged to attempt an inspiration when under water, or when the head is immersed in a poisonous air or gas, the consequence would be fatal. The muscles that perform the motions required in breathing are, therefore, partly under the control of the will, but after they have been at rest for a short time, no determination on the part of the animal can prevent them from recommencing their functions. Muscles of this character have been termed, rather rudely, *the mixed muscles*.

139. It is now time to give you a clearer idea of the nature of these highly important organs. You have been told that when you have removed the skin of a quadruped you find beneath it a layer of simple cellular tissue, perhaps containing a portion of fat (71). If you remove this by dissecting it off, you will find, in most parts of the body, a broad smooth expansion of a pearly hue, covering a red substance beneath. It is sometimes thinner than the finest paper, and almost perfectly transparent; in other places it is thick, white, and nearly opaque; while in many situations it is altogether wanting. This membrane is composed of condensed cellular tissue, strengthened by numerous fibres which are generally disposed very irregularly over and through its substance. It is called *a fascia*.

140. In reading works on physiology or medicine, you would find mention made of many fasciæ in different parts of the body; but in reality these are all connected together in various ways throughout the whole

frame, so as to constitute something like a distinct system.

141. The principal uses of fasciæ are to separate parts from each other by interposing between them something more resisting than the loose and soft common cellular tissue, and to bind down various muscles or sets of muscles, so as to give them proper and graceful form, and prevent them from starting out of their position when they contract. They also arrest or retard the passage of the fluids from cell to cell through the cellular tissue in some forms of dropsy, and exert a powerful influence in limiting the progress of inflammation or other local diseases, which pass through the fasciæ with great difficulty.

142. These fasciæ are found, not only near the surface of the body, beneath the skin, but are met with between the deeper seated organs, which they surround, cover, or envelope more or less completely, in many places. Were it possible to remove from the body all its harder portions, all its special organs, and all the loose or common cellular tissue, there would remain nothing but a series of large cells or cavities, of various sizes and shapes, composed of the fasciæ. Many of these cells would be found imperfect, communicating freely with each other in consequence of the deficiency of their walls. If you now recall to mind the fact that these fasciæ are really composed of common cellular tissue strengthened by fibres (139), and that they are embedded in, and continuous with that tissue on all sides, you will have an idea of these parts sufficiently clear for our present purpose.

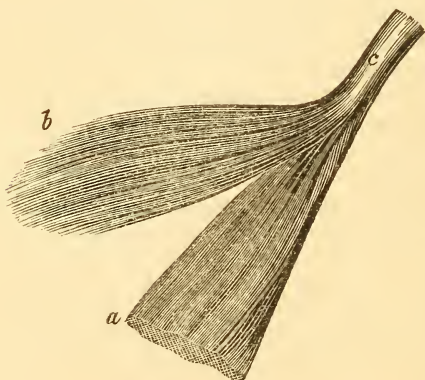
143. When you cut through the superficial fascia, in a quadruped (139), you find, in most parts of the body, the bulky red substance which we call *flesh*. To a casual observer, this flesh appears like a rude mass of matter designed to give form to the body, and to supply food for man and other animals. Such is indeed the popular idea of its nature, but the physiologist informs you that it is composed of a great number of distinct organs designed for the production of active and exten-

sive motions. Each of these organs is a *muscle*, and the whole mass of flesh taken together constitutes the *muscular system*.

144. Each muscle (except the hollow involuntary muscles, of which I shall speak hereafter) is attached at either end, to the parts which it is intended to draw together, but is generally disconnected from all other organs every where between its extremities. It is found enveloped in a delicate sheath of cellular membrane, and is surrounded by loose cellular tissue, sufficient to allow it to move freely; but the layer of this substance in which it is embedded, is often so thin that the eye cannot very readily distinguish the separation of the side of one muscle from that of its neighbour; and this is the reason why the flesh of a limb is taken for an undivided mass by the ignorant. The skilful anatomist, however, readily dissects around the entire circumference of a muscle by cutting through the loose cellular tissue only, without wounding the flesh in the least.

145. In fig. 24, you see part of a muscle thus dissected, to show its form when every thing, including the

Fig. 24.



Biceps muscle.

a, b, Fleishy portions of the muscle. c, the tendon.

bones to which in this case its extremities are attached, has been removed from around it. This is part of the double muscle of the arm, whose function it is to bend the fore-arm.

146. When we examine a muscle more closely, we find it apparently composed of a great multitude of fibres, each surrounded by its own envelope of cellular tissue. These fibres are generally collected together in small bundles, which are again associated into larger groups forming the whole substance of the organ. Each bundle, and, indeed, each particular fibre, enjoys its own particular power of contraction; so that some parts of a large muscle may be called into action while other parts remain at rest; and thus the same organ may produce various motions, according to the direction of the fibres that happen to contract. Irregular motions of one or more fibres often occur from diseases, such as convulsions or cramp.

147. The muscles of man and the more complex animals are of a bright or deep red colour: but those of animals whose blood is white, such as the insects and many other minute beings, are pearly, colourless, or sometimes even transparent.

148. The attempt has been often made to determine the actual structure of the muscular fibre by means of powerful microscopes, and some writers tell us that it consists of a row of red globular bodies connected together by transparent matter. Others inform us that no globules really exist in it, but that it resembles a cord or riband, crimped on the surface, as if thrown into zig-zag folds by its own contraction. One celebrated physiologist of the present day declares that each seeming fibre is nothing else than a very long and narrow cell, containing a fluid. Now the fact is, that such examinations, made with very powerful lenses, require a degree of knowledge, practice, and judgment which few men in the world possess; and so numerous are the sources of error, that very little dependence can be placed on the results. This investigation is highly

important to the profound physiologist, but it would only tend to confuse the mind of the elementary student.

149. Whatever the true structure of the muscular fibre may be, it is well known that the common cellular tissue, which seems to form the entire body of the simpler animals, penetrates the muscle in every part, so that when every thing peculiar to the organ has been removed by art or disease, there still remains a mass of that tissue occupying the same place.

150. Sometimes, when bones are broken, a piece of muscle is caught between the broken extremities: the fragments cannot then be knit or reunited until the vital powers have caused the absorption of all the muscular matter that intervenes; and it is found that the part is then reduced to simple cellular tissue, which does not interfere with the knitting; for, new bone is soon deposited in the tissue, and speedily joins the fragments together.

151. You can readily understand that the muscles would perform their office very awkwardly, (at least in the more complex animals,) unless attached at their extremities to parts more firm than mere cellular tissue; for how could the body be moved to any useful purpose, if there were nothing about it to prevent it from bending with equal facility in every direction? Now the necessity for such firmer parts is answered in widely different ways in different portions of the animal kingdom. You have been told that even the hydra has an external surface composed of a cellular tissue more dense, and consequently somewhat harder than the other portion of its body (65): and when we examine animals of somewhat more complex structure, we find that nature employs the true skin,—which is mainly composed of the same tissue, very much condensed and strengthened with innumerable harder fibres—as an attachment for the voluntary muscles. She also employs, for the same purpose, the fasciæ (139) or internal membranes, which are rendered strong by means of the fibres contained in their structure. The common snail

found in the damp vaults in which we often keep our meat and butter, will furnish you with an excellent idea of an animal that performs many and curious motions, and is provided with a multitude of muscles, the greater part of which are connected with the skin. The progression in all such animals is very slow, and is effected with seeming difficulty, because the parts to which the muscles are attached are so soft and flexible that they cannot be made to perform sudden and violent motions.

152. Many animals analogous in some respects to the snail, and classed by naturalists under the general name of *mollusca* or *soft animals*, have the power of secreting, upon the external surface of their mantle—a membrane formed by an expansion of their skin, that covers their bodies loosely, like a cloak—a solid shell, composed chiefly of carbonate of lime; from whence this portion of the mollusca are often called *testacea*. This shell answers the purpose of a house to live in; and although the animal can never leave it, it can thrust the body out or draw it back at pleasure, by means of certain large and strong muscles attached to the shell within its cavity. But even in such animals, all the muscles which enable them to crawl and carry their shell about are connected with the skin, which, in many places, is very thick and hard. You can often find small snail-shells beneath damp boards in the garden, in the moist earth about the lower part of fences, or under the bark of decaying logs or stumps in the woods. By the side of almost any large brook or river you may gather quantities of shells inhabited by animals of the same class, and if you keep a few of these for some hours in a tumbler of water, choosing such as have no hard covering over the mouth of the shell when the animal retires within it, you may now and then enjoy the opportunity of seeing them swim upon the surface, displaying in the most beautiful manner the slow motions produced by muscles which arise from one portion of the skin and are inserted into another.

153. There is a large class of marine animals known by the *very hard* name of *echinodermata* or *spiny*

skinned animals, in which we find the true skin not covered by a simple cuticle alone (96,) but also by a solid incrustation of lime, enveloping nearly the whole body. Some of these animals are formed like a star; and in these, the rays, which are often divided into many branches, are employed as limbs to walk with. The hard incrustations of these rays and their branches are divided transversely into very numerous segments or rings bound together by a more flexible horny matter; and the muscles of locomotion, passing from one ring or segment to another, serve so to bend them as to enable the animal to move along the sand at the bottom of the ocean. You may find animals of this character dried, and preserved in cabinets by the improper name of starfish. They are very common on the shores of inlets from the sea.

154. In some of the members of this class, known by the popular name of sea-eggs, there are no rays, the body being of a form approaching to the globular; but the external surface of the incrustation is studded with raised balls of the same substance, perfectly smooth and polished. To each of these balls a strong spine of solid carbonate of lime, sometimes very thick and long, is attached by means of a regular socket exactly fitting the round surface of the ball; and these spines are moved by muscles attached to them, so as to enable the animal to push or roll itself along. The sea-eggs are common on sandy coasts in hot countries, and among rocks in northern climates. You will find their shells or crusts, (sometimes with spines attached, but more frequently without them) in almost every collection of shells.

155. I need not explain to you the manner in which insects and also crabs (*crustacea*) employ the jointed horny or calcareous plates which are formed in their cuticle and bound together by it. To make yourselves acquainted with the motions of insects, you have only to examine a fly or beetle; and if you live so far from the sea that you cannot procure a common crab or a lobster, you can find a crawfish at any time by turning over a few flat stones in the nearest rivulet where the

water runs rapidly. The muscles of locomotion pass from one segment to another in these animals, as they do in the star-fish.

156. The external hard coverings, or, as they may be termed, the *external skeletons*, of the testacea, the echinodermata, insects, and crustacea, may all be regarded as appendages of the skin, being secreted by that membrane, as the solid stems of coral are secreted by the bodies of the polypi (95, 96.) They resemble more or less the nails, horns, scales, and beaks, of man, quadrupeds, fishes, and birds. Like the outer bark of plants, these parts possess no life, and are subject to being worn away by friction and injuries, and afterwards reproduced. Insects and crustacea cast off their hard covering at certain seasons, and form new ones adapted to their changes of shape and dimensions.

157. But you will readily conceive that external skeletons like those of the crustacea and insects would be very ill adapted to the necessities of the larger and more important animals. The accuracy of the sense of feeling would be destroyed over nearly the whole body by such an arrangement, while the freedom of motions would be greatly impeded by the rigidity of the envelope. The bulk, weight, and rapid and powerful motions characterizing the members of the higher orders of the animate creation seem also to require a solid internal frame-work, to give strength to their several parts. Accordingly, we find the reptiles, fishes, birds, quadrupeds, and man provided with another system of solid organs, situated within the body, and connected together by numerous joints. This is called the *osseous system*, and the individual organs which compose it are the *bones*.

158. All the voluntary, and most of the mixed muscles are either directly or indirectly connected at each extremity with the bones; and it is by the motions of the osseous system, produced by these muscles, that all the voluntary actions of the animal are effected. Nothing analogous to true bone is found in animals of less dignity than the reptiles and fishes.

159. Even the bones of the most perfect animals are soft and flexible at a very early age; and, at a somewhat later period of existence, a portion of almost every bone is still found in the same condition. It is not very uncommon to see the arm of a child two or three years old bent and deformed by a fall, without being actually broken; and it may be then restored to its proper shape by the surgeon without producing a fracture. Bones are originally formed of soft cellular tissue, filled with a kind of glutinous fluid. After a time, this fluid is gradually absorbed, and a white, elastic substance, resembling what anatomists call *cartilage*, commonly known by the name of *gristle*, is deposited in its place. The bones then become firm enough to be useful to small or very young animals, and also to some beings of much larger size, that, living entirely in the water, have their weight supported by the fluid in which they float, and are therefore less liable to falls and heavy blows. A very large family of fishes are found to possess an entire *skeleton* composed of gristle alone. Even the jaws of that terrible animal the shark, are composed of this material, and a portion of the ribs, in man, remains in the same condition during life.

160. But the necessities of most of the more perfect animals, when full grown, demand a *skeleton* or bony frame-work for the body, that is very hard and inflexible. The bones are brought to this condition by the deposition of earthy matter within the substance of the gristle; and this deposition becomes at last so considerable that these organs *appear* to be entirely composed of it. Two salts of lime, the phosphate in great abundance, and the carbonate, or common chalk, in small proportion, constitute nearly the whole of this earthy matter.

161. If we heat a perfect bone for a long time in a furnace, all the gristle will be burned out, and the whole will crumble easily under the fingers like a piece of chalk, because the animal matter that bound the earthy particles together has disappeared. By long boiling in water, much of the animal matter may be removed, and the bone reduced to nearly the same condition.

162. On the other hand, if we place one of these organs in a large quantity of dilute acid, the earthy matter will be gradually dissolved, as in the case of the eye-stone surrounded by vinegar (13); and then the gristle will remain, preserving the form of the bone most perfectly, yet becoming so flexible that it may be tied in a knot without breaking, if the specimen be long enough for the purpose. One of the bones of the fore-arm reduced to this condition and thus tied, may be seen in fig. 25.

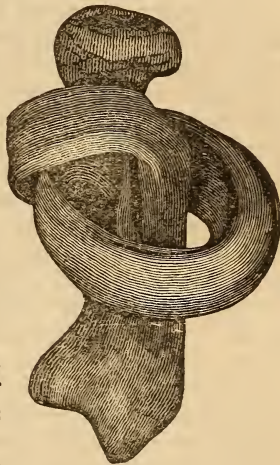
163. By a careful and difficult process even the gristle may be removed, so as to leave nothing but the soft cellular tissue in and by which the bone was originally formed. By preparing a bone thus reduced with spirit of turpentine, it may be rendered so transparent that you can read a book through its thickness.

164. The changes thus effected by art, are often accomplished in the living body by disease. There is a very terrible affection sometimes seen in Europe, but scarcely ever in this country, which reduces all the human bones nearly to the condition of gristle, so that they will bend with the weight

of the body or the limbs, until the unfortunate patient becomes horribly deformed and finally dies. In scrofulous or cancerous complaints, a part or the whole of a particular bone may be reduced nearly to simple cellular tissue;—and in consequence of this change, I have known a person to break an arm by simply turning in bed. In a few rare instances, the gristle and earthy matter have been restored by the vital powers after such an alteration.

165. From what has been already said of the struc-

Fig. 25.



Bone deprived of earthy matter.

ture of muscles and bones, you are now prepared for the statement of a general truth, which I introduce in this place in order to avoid the necessity of frequent repetition. Every part of the body of an animal, and consequently every organ that it contains, is composed, in part, of cellular tissue: after death, it may be reduced by art to the condition of simple cellular membrane. Any organ not essential to life may undergo this change in consequence of disease, and may be restored by the vital powers to its former condition.

166. This membrane, which, as you have been told, seems to form the entire body of the simplest animals, such as the hydra (65), is really the instrument by which all the organs are created. There is a time in the history of every animal before birth, when the body is composed entirely of cellular membrane, and is as simple in its structure as the hydra. The younger an animal is, the more nearly all its organs approach to this simple state.

167. When an earth-worm is cut in half (43, 44), it is the cellular tissue that grows, so as to form a new head or a new tail. And when the leg of a salamander (a little water lizard) is bitten off by a bird, or a fish, the same tissue buds out, like the branch of a tree, and forms a new limb, gradually constructing within itself the bones, the muscles, and all the other organs belonging to the perfect member. So, in man, when he is wounded, it matters not whether the injury occurs in a bone, in a muscle, or any other particular organ, it is always the cellular membrane that first unites or heals, and the matter peculiar to the organ is afterwards deposited within it.

168. Why it is that cellular tissue should form a bone in one part of the body, a muscle in another, &c., we know not, because the principle of life—the power that regulates the vital functions — is a mystery beyond the reach of human learning.

169. But let us return from this digression. It is scarcely necessary to tell you that the skeleton is composed of a great many bones, most of which are connected together by movable joints. If the extremities

of the bones at the joints were permitted to come in contact with each other, without the interposition of any softer matter, there would be great danger that the edges of the bones would be broken off in consequence of slight falls, blows, or violent motions; for bone is very brittle, and cannot be compressed. To guard against this danger, the extremities of the bones, where they form movable joints, are covered with a thick cap of white elastic matter called *cartilage*.

170. Cartilage bears a strong resemblance to the gristle of which the entire skeletons of many full-grown, and those of all very young animals are formed (159), and hence anatomists have termed the elastic covering of the joints *the articular cartilages*, to distinguish them from all other organs of somewhat similar appearance.

171. You may examine for yourselves the structure of the articular cartilages in the joints of any of the larger animals when cooked for the table; for, although the process of roasting or boiling alters them considerably, they will still serve your purpose very well unless they have been overdone. A knuckle of veal or a pig's foot will furnish you with the best example, and may be examined in the kitchen before it is dressed. One such examination will give you clearer ideas than a volume of description.

172. To prevent friction between the articular cartilages when the body is in motion, every movable joint is provided with a delicate sac of very thin and perfectly smooth membrane, called a *synovial membrane*. This lies between the articular cartilages, covering them so closely wherever it touches them that it can scarcely be separated from them; but at the sides of the joints the membrane is much less closely connected with the surrounding parts; so that it may be more readily seen. The synovial membrane or sac always contains a small quantity of a peculiar unctuous fluid called *synovia*, which answers the same purpose with the oil that we pour upon the axle or pivot of a wheel to make it turn more easily; and this fluid is secreted by the membrane which contains it.

173. When we were speaking of that form of contractility which is called *tonicity* (115, 116), you were informed that the habitual tone of the muscles keeps the bones, or rather the articular cartilages, always pressed against each other with a certain degree of force. But, in extensive and sudden motions of the members, the bones would be continually liable to be put out of joint, or dislocated, were they not bound together by some firmer material than muscle, and one less capable of being stretched or contracted. To secure the animal against such accidents, the joints are provided with another set of organs called *ligaments*.

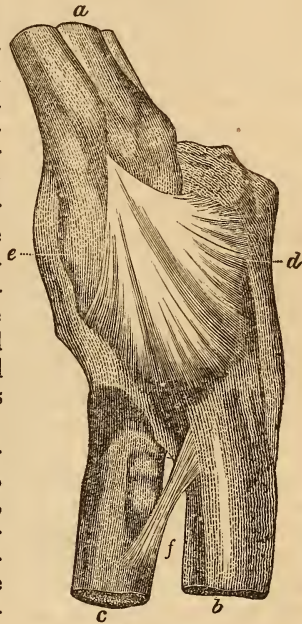
174. The ligaments are composed of cellular tissue very much condensed, and strengthened by strong and numerous fibres. They are white like the fasciæ, inelastic, and cannot be suddenly stretched to any considerable extent except by most violent forces. Though flexible like membranes, and soft to the touch, they are much stronger in proportion to their size than the bones which they bind together. Their principal function appears to be the prevention of too extensive motions in the joints; for many of them remain perfectly loose while the bones are in an easy or common attitude, but when they are bent as far as they are intended to go, some of the ligaments are drawn tight, like cords, and thus prevent either the muscles or slight accidents from moving the joints any further. Let me give you an illustration. The leg, in man, is intended to bend backward in walking, and to remain straight in standing. It can be bent backward until the heel touches the thigh, without straining any of the ligaments, because the thigh itself prevents it from being carried further in this direction than is suitable to the wants of the animal. But if you endeavour to bend the leg forward or to either side, you soon find it impossible, because there are very powerful ligaments on the sides and in the interior of the knee joint, which are put on the stretch whenever you attempt to cause such a motion. Tremendous forces sometimes dislocate the strongest joints; but, whenever this occurs, either some of the ligaments are

broken, or the parts of the bones to which they are attached are torn off. The latter accident is even more frequent than the former. In fig. 26 you have a representation of the ligaments of the elbow joint.

175. You have been told that each of the muscles is inclosed in a kind of sheath or covering of cellular membrane or fascia (144). Each of the bones is inclosed in a similar manner by a membrane composed of cellular tissue strengthened by very numerous and irregular fibres, so that its structure bears considerable resemblance to that of the ligaments. As we may have occasion to mention this kind of membrane again it is well to name it at once. It is called the *periosteum*.

176. The periosteum adheres very firmly to the bone, and covers all parts of it, except those which give origin or insertion to the ligaments and muscles, and those which are coated with cartilage. In some places, the periosteum is extended over the surface of a cartilage; and the membrane then takes another hard name. It is not essentially changed in its nature, and it is hardly right to task your memory with its title. It is called the *perichondrium*. The periosteum covering the outside of the bones of the skull has received the name of *pericranium*.

Fig. 26.



Ligaments of the Elbow Joint.

a, The bone of the arm. *b, c*, Bones of the fore-arm. *d*, A lateral ligament of the elbow joint. *e*, The capsular ligament of the elbow joint. *f*, A ligament connecting the bones of the fore-arm.

177. Having now enumerated the principal classes of

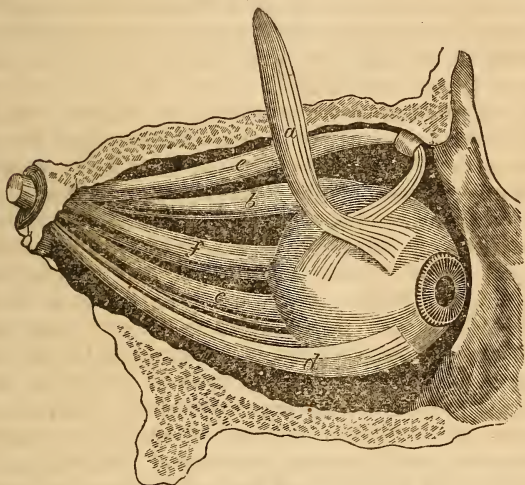
organs, &c., that belong or are appended to the *osseous or bony system*, namely; the bones, the cartilages, the ligaments and the periosteum; let us return for a few moments to the muscles.

178. Most of the voluntary muscles are large, for they are designed to exert great force. Now, if they were so formed as to preserve the same fleshy and bulky character throughout their whole extent, the joints which they surround or cover in their passage from one bone to another would be buried as deeply as any other parts of the bones. The elbow would be at least as thick as the arm, and the knee would rival the calf of the leg. Moreover, the bones would not present sufficient surface for the attachment of such a multitude of fleshy fibres. All symmetry of form would be destroyed, and the strength would be exceedingly diminished. But, to prevent these inconveniences, the muscular fibres of many of the principal voluntary muscles are made to terminate in much finer fibres of a pearly hue, possessing far greater strength than those of the red, fleshy portion of the muscle. These smaller fibres are crowded together so as to occupy very little space in comparison with the more bulky part of the organ. Any bundle of such fibres which may be connected with a single muscle is called a *tendon*. A drawing of one of these accessories belonging to a double muscle is seen at fig. 24, where *a* and *b* represent portions of the two fleshy bellies of this muscle, both terminating in the single tendon *c*.

179. Some of the tendons are round, like a cord, and others are flattened until they resemble a very thick fascia, from which, indeed, they do not differ very widely in composition. One of the former kind you may examine in your own person by grasping the back of your ankle an inch above the heel. The thick hard cord that you feel there is a tendon connected with the muscles that make the foot point downwards, or lift the whole body when we stand on the toes. Small as it is, every fibre of the flesh composing the bulk of the calf terminates in it.

180. The tendons do not contract like the fleshy fibres, nor can they be stretched any more than the ligaments (174). They act like simple ropes or bands to connect the ends of certain muscles with the parts that those muscles are intended to move. The mechanical arrangements of the tendons in the larger animals and man are often exceedingly curious. Some of them run over pulleys formed by grooves in the bones near the joints, which pulleys are covered with cartilage and synovial sacs to prevent friction (172). Sometimes

Fig. 27.



Section of the Orbit. The Human Eye and its Muscles.

a, The outer straight muscle of the eye, cut off from its attachment at the bottom of the orbit, and turned up to display the other parts. *b, c, d*, The other straight muscles. *e*, The superior oblique muscle, with its tendon running through a cartilaginous pulley near the edge of the orbit, and turning back to be inserted on the outside of the globe of the eye. *f*, The optic nerve.

they are bound down in their places by ligaments which stretch across the grooves. Some of the tendons are perforated by smooth openings, resembling button-holes, through which other tendons pass to reach their destination. But one of the most curious of these arrangements

is seen in an oblique muscle of the eye, of which the tendon runs through a pulley within the orbit, and then doubles itself backward, so as to move the eye in a direction opposite to that of the motion of the muscle. (See fig. 27.) If you wish to examine the action of a tendon for yourself, take the leg of a dead bird; cut off the skin with a sharp knife, and draw with your fingers any of the white cords that surround the bone. You will immediately see a motion produced in the foot or claws, and the kind of motion will depend upon the tendon which you happen to have seized. In birds, some of the tendons are often partly composed of bone; and the cap of the knee in man, though a bone, appears to belong rather to the great tendon of the muscles on the front of the thigh than to the skeleton, with which it is not directly connected.

181. The involuntary muscles are rarely provided with tendons. They are scarcely ever formed into distinct masses, like the voluntary muscles; but, are nearly always composed of fibres interlacing or overlapping each other in various directions; and, instead of being connected with the bones or hard parts of the animal, they are usually found spread out, like a membrane, around some hollow organ, such as the stomach for instance, to which they furnish a distinct coat called the muscular coat. When called into action, the fibres of the muscular coat contract in such a manner as to expel the contents of the organ that they envelope. All parts of the alimentary canal of the more complex animals are provided with a muscular coat, designed to drive forward the food and its products, as the process of digestion advances.

CHAPTER VI.

ON THE GENERAL DIVISIONS OF THE VASCULAR SYSTEM.

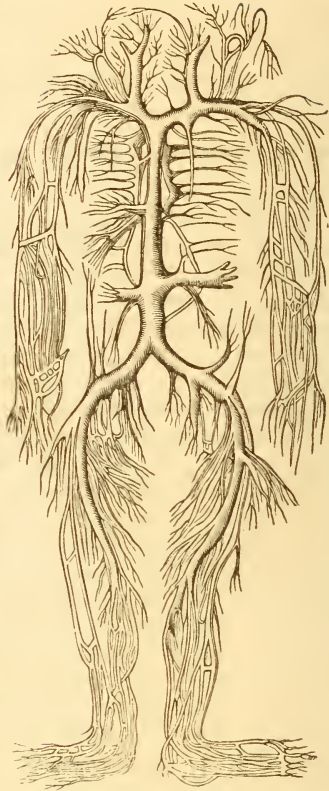
182. MANY of the organs that have been mentioned are large and solid. Their structure, and, consequently, the materials of which they are composed, are very various. In some of them we observe many different kinds of matter combined to form a single organ. Thus: in each of the bones, when perfect, there are found the cellular tissue, the cartilaginous matter, and the earthy substance or lime (160). Now these various and often very complex organs, must be provided with the materials necessary for their growth and support from the same nutritive fluid; and you will naturally conclude that it would be scarcely possible to convey this fluid throughout all parts of a machine so complicated, by suffering it to pass from cell to cell through the whole body, as in the polypi (59, 60.) Nor could it be more conveniently distributed by means of a stomach branching and sending canals to every part, as occurs in the medusa (122). Accordingly, we find that in all the more important animals, the nutritive fluid formed by the process of digestion in the alimentary canal, instead of being absorbed into the general cellular tissue, as in the hydra, &c. finds its way, by a process that will be explained hereafter, into a great number of minute vessels, canals, or tubes, that all tend toward some common centre or receptacle in the substance of the body, entirely distinct and removed from the alimentary canal. These tubes or canals are known by the general name of *the blood-vessels*, and the nutritive fluid having been sufficiently prepared to enter them by the first steps in the process of assimilation (47, 48), is then properly called *the blood*.

183. The blood-vessels through which the blood flows toward the common centre just mentioned, are called the *veins*; and in animals placed high in the order of nature, the minute veins are found in every part of the body in countless numbers. To obtain some idea of their number and arrangement, you may glance at the figure of the venous system in man, as represented in fig. 28.

184. The blood in the veins is constantly flowing toward the common centre or receptacle (182); for these vessels are generally provided, internally, with numerous valves or flood-gates, which will not allow any thing to pass in the opposite direction. The structure of these valves you will be better prepared to understand hereafter, but fig. 29 will convey some idea of their appearance in a vein that has been laid open.

185. The common centre or receptacle is very differently constructed in different animals. In insects and worms it is merely a single very large blood-vessel, running lengthwise along the back, and provided with a muscular coat or some such contrivance to force the blood forward towards the organs that it is intended to

Fig. 28.



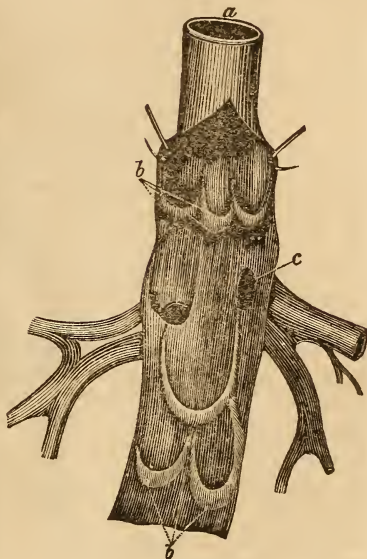
The General Venous System.

nourish. In the higher orders of animals, it is a very strong hollow muscle, designed to receive a small quantity of blood at a time, and then, by contracting, to urge that quantity onward. The receptacle, when constructed in this manner, is called *a heart*; and the beating of the heart, as it is called, is produced by the motion of this most important organ in pumping its contents.

186. When the blood from the veins has filled the heart or the great vessel that answers the same purpose, it is necessary that it should be conducted through another set of channels to all parts of the body, and into the substance of every organ, in order to nourish it. For this purpose another set of blood-vessels, called the *arteries*, is provided. One or more great arteries originate from the heart, and pursue their course toward the extremities. Each artery soon branches into two or more trunks, and each trunk is again and again divided, until at length the number of branches exceeds all calculation; and there are few parts of the body into which a pin can penetrate without wounding one. For a general idea of the distribution of the arteries in man, you may refer to the view of the arterial system as represented in fig. 30.

187. The current of blood produced by the action of the heart is very rapid; and you are not to suppose that any part of the body employs all the blood which is sent

Fig. 29.

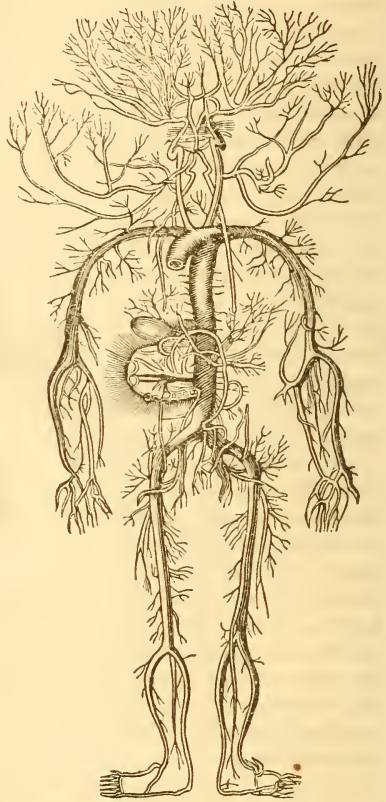


A Vein laid open to show the Valves.

a, The trunk of the vein; *b*, *b*, the valves;
c, a branch of the vein entering it.

to it for its growth or sustenance. In fact a very small proportion of the whole amount is actually converted into cellular tissue, muscle, or other solid matter, in the course of a single day. But the heart drives forward so much, at every beat or pulsation, that, in a full grown, healthy man, all the blood in the body must pass through that organ several times in an hour. You perceive, therefore, the necessity of some connexion between the arteries and the veins, in order that the blood driven by the heart through the arteries into the organs, may be returned through the veins to the heart. This communication is effected by the continuation of the extremely minute branches

Fig. 30.



The General Arterial System.

of the arterial system into the equally minute roots of the venous system: so that if you inject a large quantity of coloured water into the principal artery of an animal, soon after death, the water will pass into the veins, and return through them to the heart. The smallest divisions or ramifications of both sets of blood-vessels are scarcely, if at all, visible to the naked eye; and as

they are as fine or finer than a hair, they are called by physiologists the *capillaries* or *capillary blood-vessels*.

188. What you have now been told will give you some idea of the nature of the *circulation*, which is that process by which the blood, in those animals that are provided with blood-vessels, is kept continually in motion toward and from every part of the body.

189. The more closely you study physiology and natural history, the more you will be surprised at the gradual and beautiful manner in which one organ is added after another, as you proceed from the observation of the more simple to that of the more complex animals; you will observe that each of the principal vital functions, which, in the hydra, is performed seemingly by the skin or the common cellular tissue, requires, in the higher classes of animals, a peculiar system of organs; you will see this system rendered more and more complex as animals rise in what has been termed the scale of nature; and the performance of the function will be found more and more perfect in proportion to this complexity. Common cellular tissue may digest well enough to support the frame of a hydra (72,) but it is not sufficiently active to nourish an insect: and insects have, therefore, a very complex alimentary canal for digestion. Again: The contractility of the cellular tissue alone may be sufficient to drive the nutritious fluid to all parts of the body of a polypus, but it would fail to answer the same purpose even in an earth-worm; and an earth-worm is, therefore, provided with blood-vessels and a proper circulation.

190. In most perfect insects, (that is, in most of those that have reached their full development, like the caterpillar that has become a butterfly,) the circulation does not appear to be complete. They have a large blood-vessel running along their back, often terminating at either end in some branches which have been supposed to open into the general cellular tissue of the animal. In this blood-vessel, which is highly contractile, the fluid is driven onward in waves, sometimes in one direction and sometimes in the other, but generally from behind forwards.

This blood-vessel may be regarded as an artery; but as veins have been detected in very few insects, it is still believed by many that the blood is merely agitated or mixed in this vessel, which is supposed to receive it by suction or absorption from the cellular tissue at one of its extremities and at certain other places, and to drive it out into the same tissue at the other extremity. In several of the imperfectly developed insects, such as those larvæ* which come from the water and afterwards form the dragon-fly, we find a complete circulation, and these animals furnish us with the simplest example of a circulatory apparatus. It consists of the dorsal vessel just described, and another which may be considered as a vein, running along near the under surface of the body. These two vessels communicate with each other at either end by means of numerous branches; they both send out several lateral ramifications to various parts of the body and limbs, and there can be no doubt that these branches communicate with each other in the substance of the various organs. The blood in these larvæ is seen to flow from the tail toward the head, through the principal artery or dorsal vessel; and, as it passes, it sends its divided current into the smaller arteries till these become too minute for examination. We can then detect it flowing through all the little veins toward the principal vein or inferior vessel, through which it is constantly moving from the head toward the tail; whence it is forced to return again into the dorsal vessel.

191. In the leech, and most marine worms, we find several other large vessels running longitudinally, and receiving a portion of the blood, for purposes that you are not yet prepared to understand; but, like the inferior vessel, they return this blood to the great artery. Even in animals apparently so insignificant as the oyster and other shell-fish, but which take higher rank than the

* Most insects pass through at least four forms or conditions during their lifetime. — 1. The egg. 2. The larva. 3. The pupa. 4. The imago. In the silkworm, you may easily make yourselves acquainted with these changes. The larva is the worm, the pupa is found wrapped up in the cocoon, and the imago is the perfect fly.

insects from their organization, we find the circulation much more complex, for they have no longer a single dorsal artery but a regular heart, sending the blood into many sets of vessels. You will not be surprised, then, to hear that the circulatory system in man is explained with difficulty to those who have never considered that system in those animals which are very simple in their structure. After these remarks, however, I trust you will find it an easier study when we reach the subject.

192. You have been promised an explanation of the process by which the nutritive fluid makes its way from the alimentary canal into the blood-vessels (182,) and it is right to say a few words upon that subject here. That peculiar kind of absorption seemingly resident in cellular tissue, by which it takes into the body the nourishment derived from the food in the hydra (59, 60) and the medusa (122, 123,) is commonly called *imbibition*. We know nothing of its nature, it is true, but we know that it takes place, and it is therefore convenient to give it a name, as we do when we call the power which makes a stone fall to the ground *attraction*, though we only know the simple fact that stones will fall to the ground when unsupported.

193. By imbibition, then, it is probable that the nourishment extracted from the food by digestion, (which crude nourishment we call the *chyme*,) is taken into the cellular tissue of insects, worms, and other animals with a very simple circulation; for we cannot trace any intermediate passages between the circulatory and the digestive apparatus in these animals. Now no openings are known to exist in the sides of the blood-vessels; and these vessels, like all the other organs of the body, however complex, are formed originally of the cellular tissue. It is, therefore, reasonable to conclude that the nutritive fluid, after entering the substance of the animals just mentioned, is carried thence into the blood-vessels by *imbibition*.

194. But here I must pause to explain some other facts. The chyme, while it remains in the alimentary canal, is as yet imperfectly assimilated (47, 48,) and requires

further changes to fit it for entering the circulatory apparatus. These changes probably commence at the moment of its first imbibition; and when it has once entered the substance of the body, it is called the *chyle*. Even the chyle is not exactly similar to the blood in animals that have a circulatory apparatus, but requires to be mingled with that fluid, and to circulate for a time before it becomes fitted to nourish the several organs of the body. These facts are ascertained by examinations made upon the larger animals, and you will comprehend them better hereafter.

195. In the higher orders of animals, the chyle is never found wandering in the cellular tissue, as it may be, perhaps, in insects, (190,) but is conveyed to the blood-vessels through another set of vessels, called the *lacteals*. These, though they supply the blood by carrying into it the nourishment extracted from the food, are not a part of the circulatory apparatus, but constitute a separate system of canals passing from the bowels to the blood-vessels—a system unknown in the simpler animals.

196. The chyle in the lacteals is always white or milky, even in those creatures whose blood is red. Yet it is an organized fluid, and contains globules, like the blood and the sap of some plants (49), though of smaller size than those observed in the arteries and veins.

197. The lacteals originate in countless numbers from the internal surface of the alimentary canal below the stomach. There is no reason to suppose that their mouths stand open, so as to drink in the nourishment from the chyme (193) as it passes; but they imbibe this nourishment through the cellular tissue, of which their sides are formed; so that there is no direct communication between the lacteals and the bowels. These vessels, like the fine branches of the roots of a plant—which seem to answer the same purpose in the vegetable kingdom—continually join with each other so as to form larger trunks as they pursue their course toward the centre of the circulatory system (182, 183,) until at length they are all collected into one great canal, called *the thoracic duct*, which opens and pours its contents

into one of the largest veins of the body, just before it enters the heart.

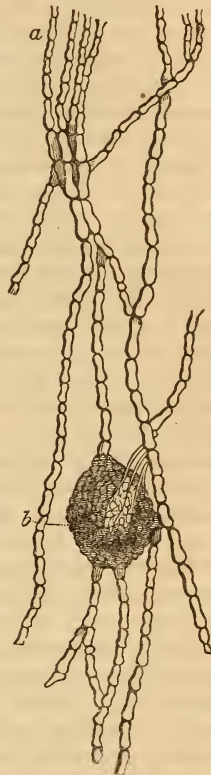
198. The lacteals are furnished with valves, like the veins, to prevent the chyle from flowing in any other direction than towards the blood-vessels; but these valves are much more numerous, occurring so frequently as to give the vessels a peculiar knotty appearance; as you see in fig. 31.

199. You have been already informed (194) that the chyle is but imperfectly assimilated when it first enters the body, and requires further changes after it enters the blood, in the route of circulation. Now it appears that in those animals which are furnished with lacteals the chyle is continually changing, and becoming more and more assimilated, from the moment of its first imbibition until it reaches the thoracic duct (197). In order that time may be allowed for this mysterious change, the lacteals pursue a very winding course, and every here and there they are studded with little rounded bodies — fig. 31, *b*, — into which several branches are seen to enter, and from which a smaller number of larger trunks usually make their exit. These bodies are called

glands, and in their interior, the little lacteal tubes are rolled and tangled together, like a bundle of fishing-worms, so that they very considerably increase the length of the route by which the chyle has to travel toward the blood-vessels.

200. By this time you must be much less surprised

Fig. 31.



Lacteals.

a, Branches of the lacteals.
b, A gland.

than formerly at learning that many of the simpler animals may be cut to pieces without being killed. For, if a polypus be divided, each piece is capable of digesting its food, and may grow:—if a worm be cut in half, each end has part of all its great blood-vessels and some of their connecting branches left; and it can still carry on a circulation, provided the ends of the vessels contract so as to keep it from bleeding to death:—but, in a quadruped or bird, if the main trunk of the lacteals be injured, the creature must starve, even though he may continue to digest his food and his circulatory system be in perfect order. His nourishment cannot then reach the blood-vessels, and of course his organs cannot be supported for any great length of time.

201. The lacteals, however, are not the only vessels that convey substances into the circulation, though there is every reason to believe that they furnish the only very important route through which nourishment can be introduced in the larger animals. Let me explain. If you put a blister upon any part of the body, you can easily cut away the cuticle or scarf-skin (28), so as to lay bare the true skin beneath; but you do not produce a wound, or lay open any blood-vessel by so doing. Yet if you then dust the blistered surface with certain medicinal powders, these will be found to act on the patient precisely as if they had been taken into the stomach: and, in most cases, these effects can be rationally explained on no other supposition than that part of the medicine is absorbed and carried into the circulation. There is every reason to suppose that water, mercury, and some other substances are even imbibed through the cuticle so as to enter the blood. When a poisonous snake has bitten any part of the body, the poison very soon circulates and produces the most serious consequences; and I could recount a thousand facts of a similar nature. Some substances artificially introduced in the extremity of an animal, through a wound, have been afterwards found in the blood, and have been actually collected from it. Now, here there are no lacteals to convey these matters into

the circulatory system. How, then, do they arrive at their destination?

202. It is thought by many, that the veins of the part may sometimes imbibe these substances directly. And, indeed, we have reason to believe that, even in man, the cellular tissue and the blood-vessels retain the power of displaying all the functions that they perform in the hydra, the medusa, or the earth-worm; imbibition among the number (58, 59, 189); though these functions are far too feebly exercised to supply the wants of so noble a creature as the lord of creation.

203. But anatomy displays for us another route through which these substances may and actually do reach the circulation. We find in the more complex animals a countless multitude of little vessels originating from almost every part of the body, even from the interior of almost every organ. These vessels are very much like the lacteals; but they are constantly filled with a colourless or slightly bluish fluid, called the *lymph*, and the vessels themselves are called the *lymphatics*. The lymph is always flowing towards the centre of the circulatory system, and the vessels that convey it are continually uniting into larger trunks, a great majority of which empty into the general receptacle of the lacteals (197), where their contents are mingled with the chyle before it mixes with the blood. The other lymphatics empty directly into some of the larger veins.

204. To prove that the lymphatics do actually convey to the circulation some of the substances mentioned at paragraph 201, it is only necessary to state, that poisoned wounds not unfrequently produce most terrible effects in consequence of the poison finding its way along the lymphatics running from the part, which it inflames as it goes, so that you can trace by the swelling, redness, and pain, the extent to which the poison has travelled.

205. The lymphatics, like the lacteals, are provided with glands, which are generally found larger and more numerous about the principal joints than in other parts of the body. The glands, in addition to the uses already pointed out at paragraph 30, seem to act as guardians

against the introduction of noxious substances into the circulation; for when a poison has reached one of these organs, in following the route of a lymphatic or lacteal vessel, the cellular membrane between the worm-like folds of the canal (199), inflames and swells. The glands being each inclosed, like many muscles and other organs, in a firm covering of cellular tissue strengthened by fibres not very easily stretched, this inflammation frequently causes the vessel to close by the pressure of the swelling, and cuts off the route of the poison towards the veins and heart.

206. The lymphatics are not discovered in the simpler animals; but, in those of the higher orders, they fulfil most important purposes, which will be explained in the next chapter. When spoken of collectively, they are often called *the absorbent system*, and the individual vessels are not unfrequently styled *absorbents*. These terms are unfortunately employed by physiologists, for they are calculated to deceive the student and to lead to the belief that the lymphatics are the only organs capable of carrying on absorption; which is very far from the truth. Should I use the term *absorbent system* in the after part of this volume, you will understand me to allude to both the lacteals and the lymphatics, and when the absorbents are mentioned I do not wish to exclude even the veins, for reasons given in paragraph 202.

CHAPTER VII.

ON THE FUNCTIONS OF SECRETION, RESPIRATION, AND NUTRITION.

207. You have received in the preceding chapter some idea of the complexity of structure observed in the more perfect animals. You have seen that this complexity requires an extension and a corresponding complication

of the masticatory apparatus (124), and the digestive system (130), in order to supply proper support to the frame. The number of separate bones, muscles, and other organs demanded to enable the animal to seek and prepare food and to move it along the alimentary canal as the process of digestion advances, requires that the nourishing fluid in these animals should be confined in blood-vessels (182), and conveyed to and from all parts of the body by means of a circulatory apparatus (188), which, in its simplest form, is composed entirely of blood-vessels, but, in creatures a little more complicated, demands a heart (185) as a principal moving power to carry on the circulation. You have also learned that, at first, the admission of the nourishment into the circulation appears to be effected by simple imbibition (192, 193), but that as animals advance in the scale of nature other assistance is required to convey it from the alimentary canal into the blood-vessels. Hence the necessity for the lacteals (195). You have been told, moreover, that in the higher orders of animals certain substances are carried into the blood from the surface of the body, or from the interior of the various organs, and that for this purpose the lymphatics are provided (202, 203). Yet the circulatory system in all the more important animals is much more complicated than you would suppose, even from what you have learned heretofore; and in the present chapter I propose to introduce you to an acquaintance with certain deeper mysteries connected with it. In order to do this properly, I must quit for a time the regular course of my narrative to communicate some preliminary information.

208. It is easy to understand that, while an animal is growing and forming its various organs, it must constantly require food to supply the materials necessary for its growth; and the circulation of the blood must be continued regularly and perpetually. But why should food be demanded, or why should the blood circulate, after the animal has reached its full dimensions, when its organization is complete and perfect? You may reply that the wearing of the cuticle, nails, horns, or

other external parts, demands a supply of food and blood to make up for these losses; for such parts are continually growing as fast as they are worn away, even at a late period in life. But a very small amount of food and blood would be sufficient for this purpose; and yet the full-grown animal requires nearly as much food, and has nearly as much blood in its vessels, as the young one: why is this?

209. If you place a vase of flowers, or a living plant, under a bell-glass, you will find, in a few hours, that the inside of the glass is obscured by moisture collected in little drops all over the surface: and this experiment proves that vegetables, which absorb water by their roots (33, 34), actually give out water from their leaves and branches. In like manner, the surface of animals is continually pouring forth a fluid which we call the *perspiration*. You do not see this fluid upon the surface of organized beings at all times, because it is usually thrown off in the form of a gas that is invisible, and combines immediately with the common air. It is only when heat, exercise, or disease has increased very greatly the flow of perspiration, that we see it collected on the surface in the liquid form of sweat. But, to convince you that the fluid is at all times escaping, during health, you have only to bind closely upon your arm, or any other part of the body, a piece of India-rubber cloth or oiled silk, and, in a few hours, you will find the surface beneath it completely wet, because the fluid discharged from the skin cannot pass through the covering, and is therefore compelled to collect in such quantities as to arrest attention. If the experiment be long continued, the sweat will generally ooze out round the edges of the cloth and flow down the limb. The escape of gaseous moisture from the skin is called *insensible perspiration*; but when the discharge is condensed so as to assume the liquid form, it is called the *sensible perspiration*.

210. When you breathe upon a looking-glass for a short time, you observe the glass to become obscured by the moisture from the breath, which soon accumulates so as to gather itself into large drops that run down the glass. This proves that the same process is going on at

all times and very actively, within the cavities of the body.

211. Now this constant discharge of perspiration amounts, in twenty-four hours, to a very considerable quantity. It is a secretion (96, 97;) and like all the other secretions, is furnished from the blood. You can now comprehend one of the reasons why full-grown animals require regular supplies of food. This is necessary in order to replenish the blood continually drained by the secretions.

212. The number and quantity of the various secretions poured out from the body, and therefore taken from the circulation, is much greater than you might at first suppose. The tears, the mucus lining all the alimentary canal and many other passages, as well as the various fluids, such as the saliva, the bile, &c., that are required to assist in the digestion of food, may be mentioned as important secretions; and their formation demands no inconsiderable supply of nourishment at all ages to maintain the proper amount of blood.

213. In many fevers, the insensible perspiration is checked, and all the secretions are very much diminished in quantity: and this is one reason why the sick often have no desire for food, and why undue nourishment so frequently renders them worse by forming too much blood.

214. I must now proceed to explain another much more wonderful vital operation. If an animal in health be deprived of its necessary food, the secretions still continue until the circulation is so far exhausted that it can no longer supply the wants of life, and the animal becomes diseased or dies. In fevers, life may be sometimes preserved without food for a greater length of time than in health, because the quantity of the secretions is then diminished. The loss of the circulating fluids during partial starvation renders the animal thinner, but it will not account for the extent to which that thinness is often carried. A person who is fat at the commencement of an attack of illness, or a stout man who is compelled to submit to short allowance at sea, soon loses his unnecessary fat; and after a time even

his muscles, (particularly those of animal life) are gradually diminished in size until they can no longer perform their office, and he may become so weak as to be unable to turn in bed.

215. If deprived of all food, an animal generally dies before the solid organs of its body are so very much diminished; because the exhaustion of the fluids by the secretion stops the circulation too suddenly. But when placed in circumstances that enable it to obtain some food, but not enough, the changes which take place in the frame-work of the body are very curious. All the organs are gradually diminished in bulk, but those which are least important to life are diminished most rapidly. The heart, for instance, or the alimentary canal, is rendered feeble, but the muscles of voluntary motion may almost disappear, and the fat is only to be seen in a few places where its presence happens to be essential to the organs in or about which it is formed. If the slow starvation be carried still further, some of the less important parts of the body may be entirely removed. Ulcers break out on the extremities, and some of the organs that can be spared without the sacrifice of life are totally destroyed. I have seen most of these effects produced, in a young man, by a tumour that pressed upon and finally closed the great canal through which the chyle flows into the blood (197:) so that, although he continued to eat, and for many months partially digested his food, he was as effectually starved as if he had been inclosed in a dungeon with an allowance of food diminished every day until nothing was left.

216. Now a moment of consideration will convince you that the substances that disappear from the body, wholly or in part, during starvation, must be taken up by absorption from the organs or parts where they had been previously placed, and carried out of the body *by some means*. There is no route by which they can thus be carried out from those animals that have a circulation except through the blood-vessels; and the *blood-vessels* have no other efficient means of discharging them but by the *secretions*. Hence you see that the

exhaustion of the blood by the secretions, when an animal is deprived of food, is compensated as long as possible by the absorption of the less important particles of the body, which are carried into the circulation by the lymphatics; and, perhaps, by imbibition into the veins themselves (202.) In other words, we may say the starving animal lives for a time upon itself, eating up by internal absorption such parts of the body as can be spared under urgent necessity, to feed those organs and to continue those functions that are absolutely essential to life.

217. But starvation is not necessary to cause this constant absorption of particles from the interior of the body. I have merely selected this very striking example because you may all observe it for yourselves in the sick-room, or in persons who are ordered to subsist on low diet for a long time. The same operation is going on at all times, even during the highest health. If the organs of an adult animal in health do not diminish, it is only because the blood-vessels nourish them with new particles as fast as the absorbents carry off the old ones. If all the organs of a young animal grow stronger with time, or if the same effect is produced in any particular muscle by exercise, it is because the blood-vessels, during youth, deposit more particles in a given time than the absorbents can take up.

218. It is one of the most curious laws of life, that there is not a particle in any organized body that can fulfil its proper functions beyond a certain length of time. It must then be removed from the body and another deposited in its place by the blood-vessels: so that in a few years there will not remain in your own person one atom that now assists in forming your bones, muscles, brain, or any other portion of your frame! *You* will be the same if you live, and yet *another!* for you will be composed of new materials. It is the immortal part of man alone that preserves the identity of the individual! You can be no longer surprised that an animal whose organization is perfected requires nearly as much food to support that organization as a younger

one in which many of the organs are still in the act of growing.

219. As the blood-vessels are the reservoirs into which all the worn-out particles of the body that are no longer fitted to fulfil the functions of life are continually poured by the absorbents, it follows that the blood would become more and more impure by these additions of exhausted matter, until no longer fitted to support the frame, were not some arrangement made for the ejection of such materials from the body. This necessary duty is performed by the secretions.

220. The secretions in animals that have an organization somewhat complex are very numerous and of widely different appearance. Thus; the tears, the bile, the perspiration, the saliva, &c., are all secretions, and all contribute to purify the blood; but they bear little resemblance to each other.

221. Why the blood-vessels should secrete tears in one place, bile in another, and perspiration in a third, we know not. This is one of the mysteries of life that so often lead weak-minded philosophers to travel beyond the bounds of human reason in search of first causes, a journey that always results in the accumulation of a cargo of *words* instead of things, to be brought home for no other purpose but to confuse the minds of others, and deceive ourselves into the belief that we are acquiring a store of *facts*, while we are really endeavouring to hoard up *empty sounds*. All that we can reasonably expect to ascertain in relation to the different secretions is the anatomical structure of the parts by which they are constructed.

222. So far as the blood-vessels alone are concerned, there is one point of resemblance between all parts of the body which *secrete* or separate the secretions from the blood. The capillaries of such parts are divided, branched, or multiplied to such an extent that, when filled with coloured glue, the whole mass often seems at first sight to be composed altogether of blood-vessels; for it will be generally found of a colour almost uniformly red throughout. Such is the structure of the true skin, and

of the internal lining of the alimentary and all other canals that open on the surface of the body; called the *mucous membranes*. The true skin secretes perspiration, and the mucous membranes throw out the mucus that lines all such passages, and gives name to these membranes.

223. Many of the secretions are the work of particular organs, expressly designed to construct them. They are called *glands*, but to distinguish them from another very curious class of organs belonging to the lymphatic and lacteal systems, and known by the same general name, the glands that produce secretions are termed *the secretory glands*.

224. *The secretory glands* are as various in structure as the secretions which it is their function to produce. In some of them the capillaries are wound or bundled together like a group of earth-worms in a cup ready for a fishing excursion: in some, the minutest branches are arranged in sets more like the teeth of a fine-tooth comb; while in others, they form beautiful brushes like the rays of light flowing from a sharp point placed on the prime conductor of an electrical machine, or the groups of bristles that form a tooth-brush: but these vessels are too small to be distinguished by the naked eye, and it requires the aid of the microscope to render them visible.

225. The secretions of the secretory glands are generally poured out by the capillary blood-vessels into a multitude of membranous tubes within the substance of the glands, often as minute as the vessels themselves; and these tubes run together continually, forming trunks larger and larger until they are collected into one or more tubes or passages called *ducts*, which lead the secretion to the surface of the body or to that of the alimentary canal. And all these ducts are lined with mucous membrane, like the other internal passages that communicate with the surface (212).

226. When we throw a very fine coloured fluid with some force into the blood-vessels of a dead young animal properly prepared, the fluid can be made to flow

into the ducts of the secretory glands, and into all the passages lined with mucous membrane; but the most careful examination does not detect the slightest communication between the capillaries and the ducts or the other passages. It appears that the blood in the vessels is brought extremely near to the ducts or the surface designed to be bathed by the secretions, but there is every reason to believe that there is always an astonishingly thin layer of cellular membrane between the blood and the ducts or the surface. Through this layer the secreted fluids must pass in order to escape from the circulation; and the process by which this passage is effected is called *transpiration*;* a process closely resembling perspiration. This is one of the proofs that the cellular tissue in the more complex animals exercises all the functions that distinguish it in the hydra and the polypi, where it effects all the secretions without the aid of blood-vessels.

227. It is observed that all the phenomena of nature give evidence of a beautiful economy; and this is clearly exemplified in the history of most of the secretions. Though these fluids are composed in part, and perhaps principally, of the worn-out particles of the body (216), yet nearly all of them are made useful in some way before they leave the frame entirely. Thus the tears in man, which are secreted by a small gland within the bony orbit of the eye, are poured out through six or more little ducts running down near the outer corner of the upper eyelid, where they may sometimes be seen by reverting the eyelid. Here the tears spread themselves over the eye to prevent friction between the ball and the lids, which would be extremely irritating to an organ so delicate. They are then taken up or absorbed by two other ducts that run from near the inner corner of each eyelid to a canal leading into the nose, where they assist in preserving the moisture necessary to the perfection

* Transpiration is a term often used generically, to signify the passage of fluids or gases through membranes, internally or externally; but perspiration is a specific term signifying transpiration on to the external surface.

of the sense of smell, and prevent the extreme dryness of the mucus, that would otherwise result from the almost continual rush of air through the nose in breathing. Around the mouth there are found several glands called salivary glands, that secrete the saliva, pouring it through as many ducts into the mouth. The saliva assists in preventing too much friction from the food in the act of swallowing, or *deglutition*. It also assists in preparing the food for digestion, and probably aids in producing healthy chyme (193), for we find another gland, called the *pancreas* or *sweet-bread*, in the interior of all large animals, which secretes a similar fluid, and empties it through a duct into the alimentary canal just below the stomach, where it is mingled with the chyme as it passes from the latter organ, and before it is absorbed by the lacteals. The bile is the secretion of the largest gland in the body; called the liver, of which we shall have occasion to speak in another part of this volume. The bile passes through thousands of little ducts in the interior of the gland until these are collected into one great duct that passes into the alimentary canal at the same place with the duct of the pancreas. What part the bile plays in perfecting the chyme we know not, but there is strong reason to believe that it acts as the natural purgative, and accelerates the passage of the food along the alimentary canal.

228. But the most important, and the most universal of the secretions, is that which is carried on by the organs employed in breathing, or respiration. The function of respiration is performed by all organized beings. In plants, the leaves are the breathing organs, and their office is so important that if all the leaves be plucked or prevented from growing during the summer while the vital functions are carried on actively in the stem and branches of a plant, it will die as certainly as a man when strangled or confined under water.

229. The principal object of breathing, in animals, is to free the body from the worn-out particles of one of the principal substances that compose the animal frame; and it may be well to enumerate these substances, in

order that you may better comprehend the nature of this most interesting function.

230. Besides several metals, sulphur, and phosphorus, which contribute in small quantities to the formation of the animal frame, there are four different kinds of matter which, combined in various proportions, compose nearly the whole mass of every animal. These are, 1st, *carbon*, which we see nearly pure in the diamond, and mixed with but little other matter in common charcoal: 2d, *oxygen*, the gas or air that supports the flame of combustible bodies, and gives to common air the power of maintaining the life of animals and plants: 3d, *nitrogen*, a kind of air that will not support life, and extinguishes a candle when immersed in it, but which forms, when mixed with a proper portion of oxygen, a considerable part of the air we breathe; and, 4th, *hydrogen*, a gas that combines with oxygen to form water, and with carbon to give us the gas that is burned in our streets in the place of oil. Oil itself owes its inflammable properties to the presence of this gas.

231. Now, as the four substances above mentioned (230), combined in different proportions, and rendered liquid or solid according to circumstances, compose nearly the whole animal, and as all the particles of all parts of the animal require to be taken up by absorption from time to time, to be carried into the circulation and rejected from the body (216), it follows that the blood, as it travels through the capillaries in the substance of the different organs, must become loaded with these four substances to such an extent as to require to be continually purified from them. And as the arteries are the organs that convey the blood to all parts of the body in its purer condition, to nourish the frame (186), while the lymphatics, which empty into the veins, and the capillary veins themselves (206) receive all the worn-out particles, it is in the veins that you would expect to find the blood most in need of purification. The oxygen and hydrogen are easily discharged from all parts of the body in the form of water or watery vapour, in the sensible and insensible perspiration and other secretions.

The nitrogen escapes in many ways without the necessity of any particular organ for separating it from the blood, but the carbon is not so easily dismissed.

232. It is the presence of an excess of this substance in the veins of the red-blooded animals that gives to the blood in the veins its dark purple or bluish tint; and it is the removal of the same substance that restores the bright crimson of the blood always seen in the arteries. Now a part of the surplus carbon is got rid of in the liver by the secretion of bile; but a far greater amount of purification is demanded for maintaining the vital functions in health, and special organs are required for the purpose. These organs, taken collectively, are called the *respiratory apparatus*, and the process by which they perform their functions is called *respiration*.

233. In order to purify the blood of its excess of carbon, it is necessary to bring the circulating fluid to the external air, that its carbon may unite with the oxygen contained in the atmosphere; for it is found that wherever the living blood is thus placed, the substances just mentioned *will unite* and form that gas which is known among chemists by the name of carbonic acid; the same that escapes from beer, cider, or mineral water. Wherever a portion of air has been breathed, or submitted to the action of the respiratory apparatus of an animal, it is found that a portion of its oxygen has disappeared, and that a proportional quantity of carbonic acid gas has taken its place.

234. As many animals live altogether in the water, and as this fluid contains oxygen as well as air, it is very commonly supposed that such animals breathe the water itself. But all water, in its natural state, contains a large quantity of atmospheric air, which, though we cannot perceive it, may be extracted by art, as you will learn when you see it placed upon an air-pump. While the air-pump is being exhausted, you will observe bubbles of air continually rising through the water. Now, it is generally believed by physiologists, that fish and other animals that live altogether in the water, breathe only the air that it contains, and not the water itself; and it

is certain that all the experiments yet tried tend to prove that when water has been artificially deprived of its air, it can no longer maintain animal life ; so that a fish may then be drowned in its own element.

235. You all know that a fish, when taken from the water, will soon die ; proving that too much air will kill as effectually as too little. Thus ; although the birds, quadrupeds, and man, in breathing, use little else than the oxygen contained in the air, yet if we enclose an animal of either of these classes in a vessel of pure oxygen, he will soon die. You will now readily understand why changes of air, such as those which occur in moving from the mountains to the sea, from a swampy to a dry situation, or the reverse, may seriously affect the health of man and beast, particularly when in a feeble condition. But this is wandering from the direct course of our studies.

236. It is not necessary that the blood should actually touch the external air in order to part with its carbon ; for this operation takes place through the sides of the blood-vessels, by imbibition and exhalation or transpiration, like all the organic functions of the polypi and the hydra.

237. The function of respiration in the simplest animals is performed by or through the skin ; and even in many of those which are much more complex in their organization, some portions of the surface preserve the same power of action ; but, even in these latter animals, life cannot be prolonged beyond a definite period without the aid of a special respiratory apparatus. Thus ; we know beyond dispute that the toad can breathe through the skin of the back, and this power no doubt assists in preserving its life for a long time when shut up in the hollows of trees, or buried in fissures of rock where it can make no use of its special respiratory organs, and must depend exclusively upon the air contained in the crevices of its living tomb, or in the fluids that accidentally trickle around it. Anecdotes of toads living for months or years in such situations are not uncommon.

238. There is reason to believe that even man may

breathe, to a certain extent, by his skin; and different substances are known to find their way into and out of the body by this route. Although this kind of respiration is altogether insufficient for the purposes of an animal so noble and complex in his organization, the effect of cleanliness in promoting health and a ruddy complexion is in part due to the removal of all obstacles to the proper exercise of this function by the human skin. Many things in the history of wounds and inflammation tend to establish this fact.

239. But in all animals, except those of the very simplest character, some definite apparatus is devoted to the particular purpose of respiration; and in nearly all those whose organization in this respect is understood, the most essential part of this apparatus is formed on one general principle. One or more blood-vessels are provided, to convey a portion or the whole of the blood to some organ where it may be acted upon by the atmosphere, or by the air contained in water (234.) These blood-vessels, though they convey the impure or venous blood to the purified, appear to be constructed like an artery. Another vessel, or set of vessels, re-conveys the blood, after purification, back to the circulation; and although these vessels are thus filled with arterial blood fitted to supply nourishment to the frame, they are constructed like the veins. It is in the capillaries of these vessels and through their sides (236) that the function of respiration is performed, and the blood loses its surplus carbon.

240. The capillaries which are expressly devoted to carrying on the function of respiration are always found collected together, in such a manner as to form one or more somewhat irregular organs bearing more or less resemblance to glands (223,) and generally situated on opposite sides of the body. In a few animals these pairs of organs are fixed so near the middle line of the body that they seem to be united into one.

241. The only important exception to the general principle on which is regulated the formation of the respiratory

apparatus (239,) is found in the insects, certain spiders, and some kindred tribes that seem not to possess a perfect circulation. In the insects, the air is admitted into the substance of the body through numerous openings ranged along the side or lower surface of the animal. These openings are the mouths of as many tubes, which divide themselves in the interior into many branches communicating with each other, and bringing the air almost into contact with the nutritive fluid or blood in the cellular tissue around their organs. These tubes are called *tracheæ*, and the kind of respiration performed by them is called *tracheal respiration*. Many of the worms have also numerous openings to admit air into small sacs beneath their skin, for the purpose of respiration; but I will not saddle your memory with a description of the endless varieties of the respiratory apparatus of the lower orders of animals.

242. As a general rule, those animals that live entirely in the water have their breathing organs at or near the surface of the body. These are sometimes in the form of tufts of hair or prickles that may be useful in crawling; as in the long red worm so often seen creeping about the hinges of salt oysters. Sometimes they resemble little paddles or limbs that assist the animal in swimming; as in a few of the molluscous tribes that float near the surface of the ocean. But more generally they are composed of cartilaginous rays, with branches ranged much like the teeth of a fine-tooth comb, and covered with a delicate tissue as in the fishes.

243. All respiratory organs designed for breathing under water, and formed on the models mentioned in the last paragraph, are termed *branchiæ* or *gills*, however various their number and shape may be, and whether they are placed altogether externally, or enclosed in superficial cavities. The kind of respiration performed by them is called *branchial respiration*.

244. The different forms of *branchiæ* observed in aquatic animals are indefinite in number; but all of them are furnished with innumerable capillary vessels that

approach so nearly to the surface that they bring the blood almost into contact with the air contained in the water, in order to be purified of its carbon.

245. In many of the lower orders of animals, the branchia hang suspended in the water without any very apparent apparatus to produce a current towards them, so that they would seem, at first sight, to depend for their supplies of air entirely upon the water that chances to come in contact with them. The common fresh-water muscle of our brooks and mill-dams will furnish you with a beautiful example of this kind of respiratory apparatus. If you open one of these shells very carefully, you find it lined internally with a soft membrane called the mantle. Between this mantle and the tough, muscular, tongue-like organ lying next the opening, (by means of which the animal pushes himself along through the mud, and which is therefore termed the foot,) you see two delicate membranes on each side, resembling the leaves of a book. These membranes are the branchiæ, and the delicate misty lines which you may detect ranged like the teeth of a comb along their margin, are the principal blood-vessels of respiration, which the transparency of the animal permits you to distinguish. As no motion in these branchiæ is visible by the naked eye, you would naturally suppose that the supply of air that they obtain in still water is very small and precarious; but if you long observe one of these shell-fish in a vessel of water, when undisturbed, you will see the shell slightly open, and if there be a few motes in the water, you will soon perceive that there is a constant current running in at one end of the shell and out at the other; thus the branchiæ are supplied with fresh fluid at every moment. The microscope exposes the cause of this mysterious motion; for it displays the branchiæ covered with innumerable cilia like those of the polypi, which, by their motion, produce the current just mentioned (81, 82). When a portion of one of these membranes is carefully cut off, it is seen to move about like an independent animal by the powers of the cilia. and hence many naturalists

conclude that the latter class of organs are employed as a respiratory apparatus even by the simplest animals.

246. All animals that live in air are provided with internal respiratory organs, which are called *lungs* or *respiratory cavities*, and the kind of respiration effected by these organs is called *pulmonary respiration*.

247. The pulmonary cavities are sometimes single, and formed of a simple sac with an external opening to admit the air. This is the case with those snails that breathe in the air only. Many even of those snail-shells called *lymnææ* by naturalists that we find along the margin of our rivers and streams, living in the water, are provided with organs of this kind. They would drown if kept continually immersed; and if you observe their habits when preserved in a tumbler of fresh water, you may see them crawling up the glass at intervals until they reach the surface and take in a fresh supply of air. This they do by opening a small round orifice leading to their pulmonary cavity. When the air therein has been sufficiently changed, they close the orifice again, and carry their fresh supply with them, wherever they travel, until its oxygen is exhausted. (233). These pulmonary cavities render the animals much lighter, and assist them in floating upon the surface in the manner already described (152).

248. The respiratory capillaries in these animals, instead of being spread over the outside of solid organs, as in the branchiæ, (243) are distributed over the membrane forming the pulmonary cavity, where they bring the blood nearly into contact with the contained air,—nothing being placed between the sides of the blood-vessels and the cavity except an exceedingly thin layer of the membrane.

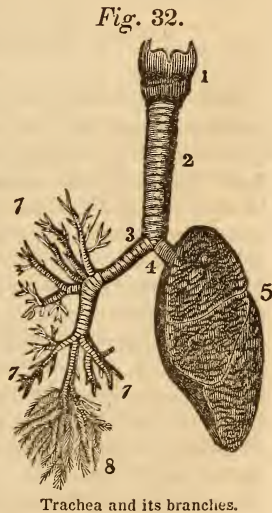
249. The pulmonary cavities of the larger animals, such as the quadrupeds, are constructed upon the same model; but instead of a single cavity, these are composed of a large mass of little cells, collected together like a bunch of grapes, but clustered in incalculable numbers, and formed into two large organs, one placed on each side of the chest, and called the *right* and *left lungs*.

Every one of these cells contains air, and the respiratory capillaries are distributed over their thin walls to purify the blood.

250. In order to admit the air to the lungs in these animals, a canal passes from the back part of the mouth, just behind the tongue, down the neck of the animal into its chest, where it divides into two great branches, one of which passes into the left and the other into the right lung. As soon as these branches have entered the lungs they are again divided, and continue to ramify, like the blood-vessels, until they become exceedingly small, and each of the minute branches terminates in a group of air-cells. You see a rude picture of this arrangement in fig. 32.

In fig. 32 you have the left lung of a man remaining entire, 5, but the right lung has had its substance and its air-cells cut away, so as to show you the large branches of the canal as they divide within its substance, 7, 7, &c., and a few of the smaller branches also, 8. Fig. 33 will give you some little idea of the manner in which the smaller ramifications, 1, terminate in the air-cells, 2, 2, 2, &c. The parts are highly magnified; the air-cells being but barely visible in the human lungs when fully distended.

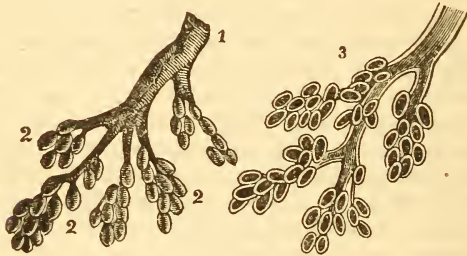
251. The great canal that passes from the root of the chest, — fig. 32, 2, — is called the *trachea*.* The principal branches passing to the right and left lungs, are called



* It is perhaps unfortunate that this organ should bear the same name with the air-passages of insects, although it performs an analogous function. It would be well for the preceptor to guard the pupil against the confusion likely to result from this identity of terms.

the *bronchiæ*, 3, 4, and the title of *bronchial tubes* is given to the various ramifications of the bronchiæ in the substance of the lungs, 7, 7, 8.

Fig. 33.



Air-cells of the Lungs magnified.

1, A minute bronchial tube ; 2, 2, 2, groups of air-cells ;
3, the same parts laid open.

252. If we compare the lungs to a gland intended to secrete the carbon of the blood, the bronchial tubes, bronchiæ, and trachea may be compared to the ducts of a secretory gland. Like all such ducts, they are lined throughout with mucous membrane, but, unlike them, are never closed or collapsed when emptied of every thing but air; for the whole length of the main canal and its branches, is surrounded by a series of cartilaginous arches or rings external to the lining membrane, which hold it open at all times.

253. The pulmonary respiration of certain shell-fish (247), requires no machinery for drawing the air into the respiratory organs and thrusting it out again; but the larger bodies of animals whose lungs are placed deep in the body, and who consume a large quantity of air very rapidly, stand in need of such an apparatus. They are therefore provided with movable bones in the chest, called *ribs*, and numerous muscles for moving those ribs, which will be more fully noticed hereafter. These muscles, when in action, alternately raise and depress the ribs; so as to increase and diminish the size of the chest and cause the air to rush in and out through the

trachea, to supply the lungs with fresh oxygen, and to remove the carbonic acid formed in them. The act of drawing in the air is called *inspiration*; and the act of forcing it out again is called *expiration*. These things you can study on your own person.

254. In birds, it is necessary that the bones should be very light, in order that they may not embarrass these animals in flying; and as the laws of Providence are such that every accidental circumstance connected with the organization of living things is rendered as useful as possible, most of the bones of birds are made hollow, and the air in breathing is admitted into their cavities, where a great number of capillary blood-vessels are brought nearly into contact with the air. Thus these cavities in the bones become a part of the respiratory apparatus.

255. You know that when the eggs of a frog are hatched, the young animal appears at first as a tadpole, residing altogether in the water, and leading the life of a fish. It is then provided with gills, and has a regular branchial respiration (243). But after a while its legs begin to grow, and its tail is diminished in length by absorption. At this time a pair of true lungs begin to be found in its chest, and the animal comes often to the surface to take in air. For a period, it retains both forms of respiratory organs; but as the lungs grow larger, the gills are gradually absorbed, until its respiration becomes entirely pulmonary, if we except its power of breathing by the skin of the back (237). When the animal becomes perfectly developed, it may be drowned by being kept too long under water.

256. In the great majority of the lower orders of those animals that have any respiratory organs whatever, only a small portion and not the whole of the blood is sent through the branchiæ or the lungs; so that the arteries are always filled with a mixed blood, partly pure and partly impure. The pure blood is that portion which is carried from the principal blood-vessels, through the respiratory arteries (239), into the branchiæ or lungs; where it loses its carbon, and is then carried back by the respira

tory veins into the principal blood-vessels again. The impure blood is that which passes directly along the principal blood-vessels from the arteries to the veins, without passing through the respiratory organs at all.

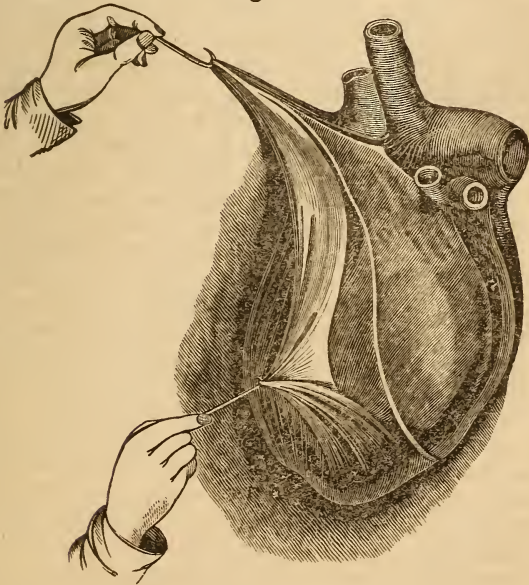
257. Now, it is found that all the vital functions are performed most vigorously in those animals whose arteries circulate the purest blood; and hence those beings alluded to in the last paragraph are remarkable for the sluggishness of their motions and functions, and for their power of retaining life for some time without air. Snakes, tortoises, and lizards, which are amphibious, are of this class; and so are a multitude of still less complex animals.

258. But in man, quadrupeds, and birds, all the blood in the veins is made to pass through the lungs before it recommences its route through the circulation; so that the various parts of the body are supplied exclusively with pure blood from the arteries. It is this circumstance that renders these animals so rapid and powerful in their motions, and enables them to display so much activity of all the vital functions, while, at the same time, it makes them more dependent upon the good quality and ample supply of air for breathing.

259. I shall not attempt to describe, in this work, the forces that compel the blood to flow through the vessels, or the various forms that the heart assumes in different animals; for you will be much better prepared to read understandingly on these matters hereafter. But it is necessary that I should give you some definitions of terms connected with circulation and respiration that we may shortly have occasion to employ. As, in the most perfect animals, the respiratory arteries carry only impure blood in order that it may be purified in their capillaries, they cannot properly support the growth and nutrition of the respiratory organs themselves. These organs are therefore supplied with another and much smaller set of arteries springing from some of the principal arterial trunks carrying pure blood. The arteries of this small set nourish the respiratory organs, but have nothing to do directly with the function of respiration. They are

called *the nutritive arteries of the lungs or branchiæ*. Both the respiratory and the nutritive arteries have their corresponding veins, to carry back the blood that they have conveyed into the respiratory organs. Those attached to the former system deliver their pure contents into the great arteries that nourish the whole frame, but those of the latter system deliver their impure contents into the principal veins that bring back the blood from all parts of the body to be purified. Thus you see that the nutritive system of vessels is completely distinct from the respiratory system, even in the respiratory organs themselves. The respiratory system of blood-vessels is called *branchial* when the animal breathes by gills, and *pulmonary* when it is furnished with lungs: but these terms are not applied to nutritive vessels.

Fig. 34.

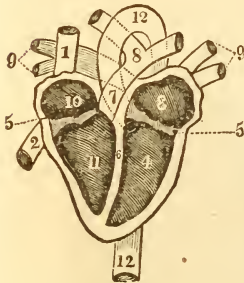


The Heart in the Pericardium.

260. To distinguish the respiratory system of vessels from that which conveys nourishment to all the organs, it has been customary to call the latter the *systematic circulatory apparatus*; but having objected to the term *system*, as applied to the whole body (25), because it is likely to confuse the mind when thus employed, I prefer the term *general or nutritive system* to designate this class of vessels.

261. It is now time to give you some idea of the functions of the heart in carrying on the circulation of blood in all the vessels of the larger animals and man. At fig. 34 you see a representation of the human heart inclosed in a thin membrane that covers it like a bag, and surrounded by the large blood-vessels that spring from it.

Fig. 35.



The Heart seen in Section

At fig. 35 you see the human heart divided from side to side, so as to show that it contains the four different cavities marked with the numbers 3, 4, 10, and 11. You see a solid division running down the middle of the organ, marked 6, separating the two cavities on the right from those on the left; and it is necessary for you to remember that you are looking at the organ as it would appear if the individual to whom it belonged were facing you, so that the left side of the heart is next your right hand. This division between the two sides of the heart in the larger animals and man is always complete after birth, except in some rare cases of disease; so that no blood can pass from the cavities marked 3, 4, to those marked 10, 11. But between the cavities marked 10 and 11 there is a division, 5, that is not complete. It is composed partly of thick muscular and tendinous matter, like 6, but there is a large opening in its centre which is furnished with a valve composed of a thin membrane that lines not only the heart, but also the whole length of the arteries. This valve is scolloped so as to form three festoons, each oc-

cupying about one-third of the circumference of the opening, with their loose edges hanging down a little toward the cavity marked 11. When the cavity 10 is full of blood, this fluid can pass easily into cavity 11 by pushing open these festoons; but when it attempts to return it arrests itself at once by forcing the festoons against each other so as to close the passage. To guard against the valve being driven upward through the opening by a sudden rush of blood, the loose edges of the festoons are secured by a number of little tendons arising from columns of muscular fibres springing from the sides of cavity 11. These tendons prevent the festoons from rising so high as to be inverted upward, which would destroy their usefulness. Between cavities 3 and 4 there is a valve, also marked 5, similar in all respects, except that it is scolloped into only two festoons.

262. The cavities marked 10 and 3 are called *the right and left auricles*. They receive all the blood brought to the heart by the veins of the two systems, the general and the respiratory (259, 260); and, when full, they contract and force it through the two valves, 5, 5, into the cavities 11 and 4. These latter cavities are called *the right and left ventricles*. All the arteries in the body, both general and respiratory, spring from these ventricles by two great trunks, each of which continues dividing again and again until its ramifications form the capillaries in the manner already described (186, 187). Now, when the ventricles contract, the blood that they have received from the auricles endeavours to flow back into those cavities, but it is immediately stopped by the closure of the valves (261); and it is therefore forced into the arteries, which furnish the only outlet. The two great arteries are also provided with valves at their origin where they leave the heart; so that the blood that has once entered them cannot flow back into the ventricles, but must flow forward into the capillaries, and thus into the veins, before it can return to the heart. These are the only valves seen in the arterial system. Although the great veins near the heart are not provided with valves, the smaller ones which unite to form them have

very numerous valves; as you have been informed already (see fig. 29, page 97); and this will explain why the auricles, when they contract, do not force their contents back into those vessels. Thus you perceive that the blood is compelled to move regularly in one direction, or to follow one fixed route of circulation. Let us trace that route.

263. All the veins from the head, neck, and upper extremities, before they reach the heart, form one great venous trunk called *the superior or descending vena cava*, fig. 35, 1; and all the veins coming from the body and lower extremities form a similar trunk called *the inferior or ascending vena cava*, 2. These two great vessels, filled with the dark-coloured or impure blood (232), meet together just behind the heart, so as to resemble but one continued vein. (See fig. 28, page 96.) At this point they communicate directly by means of a large opening in their side, with the right auricle of the heart, 10, fig. 35; into which they empty their contents.

264. At every beat of the heart the right auricle contracts and forces its contents into the right ventricle, 11. This ventricle then immediately contracts and drives the blood into the great arterial trunk that arises from it (262), which is called the pulmonary artery, 7. This artery soon divides, as you see at 8, into a right branch going to the right lung, and a left branch going to the left lung. The two branches of the pulmonary artery convey the impure blood into the lungs, and there distribute it to the pulmonary capillaries, which separate its carbon in the manner already described (239), and render it fit to support and nourish the frame. The pure or bright red blood thus formed then passes from the pulmonary capillaries into the minute branches of *the pulmonary veins*, which, as they travel toward the heart, unite continually with each other until they form four large trunks called *the pulmonary veins*, 9, 9. These branches all pour their contents into the left auricle of the heart, 3; and this forces the blood into the left ventricle, 4. When this ventricle contracts, its contents are driven into the great arterial trunk that arises from it, which is called *the aorta*, 12. The aorta is the great ves-

sel that supplies all the frame with support and nourishment. It conveys the pure blood into the general or nutritive capillaries of all the organs and into those that furnish all the secretions. From these capillaries the blood passes into the minute veins of the nutritive system, which finally unite continually into trunks becoming larger and longer until they form the two *venæ cavæ* with which I commenced this description. Such is the route of the circulation. The aorta and its branches form the great arterial system seen in fig. 30, page 98.

265. You perceive, then, that the right side of the heart, together with all the veins leading towards it, and the arteries leading from it, are filled with the dark, impure or venous blood, and the left side with its vessels contains the pure, bright, or arterial blood. The substance of the heart itself is nourished by two arteries that branch off from the commencement of the aorta, and their capillaries pour the blood into the minute branches of veins that finally empty their contents into the right auricle.

266. The total separation of the sides of the heart from each other by the partition 6, Fig. 35, has led some physiologists to speak of them as two hearts associated together; thus we hear of the right heart and the left heart; and it is a curious circumstance that in the dugong there are actually two well-formed hearts merely united together at their upper or thicker parts, each containing but one auricle and one ventricle. But if we begin to view the heart as more than one organ, we may consider it as four distinct machines with as much propriety as two; for some of the inferior animals actually have the auricles and ventricles widely separated from each other, with long vessels to convey the blood from one to another.

267. The right ventricle is commonly called *the pulmonary ventricle*, because it sends the blood to the lungs; and the left auricle is called *the pulmonary auricle*, because it receives the blood from the lungs. For the same reason the left ventricle and the right auricle are often termed *systematic*, because the former propels the blood to all the organs, and the latter receives it from them.

Hence you will find that all the physiologists speak of a "double circulation,"—"a pulmonary circulation and a systematic circulation"—in the more perfect animals and man. Now all these terms are calculated to mislead the learner, and are not founded in fact. *There is but one circulation*, during which the blood passes from the right side of the heart, first through the pulmonary vessels, next through the left side of the heart, and, lastly, through the nutritive vessels back to the right side of the heart again. But it is convenient and proper to speak of *the respiratory or pulmonary circulatory apparatus* and *the general or nutritive circulatory apparatus*; the former of which is composed, in the larger animals, of the right ventricle, the pulmonary artery, the pulmonary veins, and the left auricle, while the latter is formed by the left ventricle, the aorta with its branches, the venæ cavæ with their branches, and the right auricle. By becoming familiar with these terms, you will be able to comprehend all that you will read of the circulation and respiration here or elsewhere.

268. The capillary blood-vessels of the general circulatory apparatus—or *the general or nutritive capillaries*—are distributed in countless numbers throughout the various organs of the body; and they not only branch out in various directions, but the branches from different arteries unite with each other so as to form a complete network. Were it not for this arrangement, every surgical operation requiring that an artery should be tied, and every accident causing a division of one of these blood-vessels, would be followed by the death of all the parts of the body supplied by that vessel. But in cases of this kind the blood flows easily, through the capillaries arising from the surrounding uninjured arteries, from one part of the divided trunk to the other; and thus the current is continued. Even the larger arteries often communicate in this way in particular situations, and the veins are still more remarkable for their frequent connexion with each other, as you may observe on examining those seen on the back of your hand and wrist. These junctions are called *anastomoses*. Almost

any one blood-vessel in the body, except the aorta before it sends off its first great branches, or the venæ cavæ just before they reach the heart, may be slowly obliterated by disease without producing death, because the circulation will still find other routes through the anastomoses between the capillaries of the branches given off above and below the obstruction respectively; and these new channels will slowly enlarge themselves until they allow ample room for the current of blood.

269. But when a large artery is tied suddenly, there is great danger of *mortification* or local death in the parts nourished by it; and if all the blood-vessels of either class that communicate with an organ or member be obstructed, mortification inevitably occurs in a few hours.

270. The life of a part being thus dependent upon the supply of blood that it receives, you will not be surprised to learn that those organs whose vital functions are very active receive the largest supply of capillaries;—that all the organs of a young and growing animal have proportionally larger blood-vessels than those of adults, whose frame is already completed. Hence it is easy to understand why the young require more food than older persons, and why that food must be taken more frequently, in order to insure health.

271. The muscles receive a much larger amount of blood than the tendons or ligaments; because the former are active organs, while the latter are merely passive. The more the muscles are employed, provided they be not strained and weakened by over-exertion, the larger and stronger they grow; because the more rapid is the flow of blood towards them, and consequently the greater is the quantity of nourishment they receive. Partly to supply this additional nourishment, *the heart is made to beat more rapidly while we use exercise*, so as to hasten the circulation. Now, the more active the employment of any organ is, the faster its particles are worn out, and the more quickly they must be removed by absorption and carried into the veins to make room for fresh particles from the blood. This is the reason why

we breathe more rapidly during exercise, to purify the blood of its carbon as fast as it becomes impure.

272. If we could examine a muscle while in action, we should always find its capillaries enlarged and much more full of blood than usual; and if industry call it into habitual exertion, the capillaries become permanently enlarged; which circumstance accounts for the lasting strength resulting from well regulated labour.

273. If any set of muscles be kept permanently at rest, they gradually lose their strength; for the capillaries then become smaller and smaller, because little blood is called into them. The absorbents take up the old particles faster than the arteries deposit the new ones; and the organs are rendered thinner continually until, in extreme cases, the muscular structure nearly disappears, and the parts are reduced almost to the condition of simple cellular tissue:—a condition of things sometimes seen in old cases of palsy. This is found to be the case in those Hindoo devotees who make vows to hold an arm or a leg in a particular position without changing it for years. The muscles that should move such members are found after a time to have lost all power of contraction. I have seen a lunatic who sat crouched in the corner of his cell, during several years, without ever assuming the erect position. At last, on one occasion, a brother lunatic roused his anger to such a pitch, that he made every effort to rise and give him battle; but it was too late: he had lost the power of the muscles that enable us to stand!

274. What has been said of the effects of exercise on the muscles is true of all the other organs. When their functions are rapidly and energetically carried on, there is the same rush of blood to the part, and the same enlargement of the capillaries. Increased strength and developement follow in like manner from their properly regulated exertion, and weakness and wasting are as certainly produced by suffering them to remain too long inactive. Digestion is the proper exercise of the stomach, and you can now understand why the heart beats more quickly soon after a hearty meal, producing

the symptoms of a slight fever. Nor is it more difficult to account for the weakness of stomach that results, especially in childhood, from a deficient supply of food, or from eating that which is of an unwholesome quality. The brain is universally acknowledged to be that part of the organized being which excites consciousness and receives immediately the mandates of the will, in all those animals that have a brain, and *thinking* and *willing* furnish it with its proper exercise. Whenever the mind is occupied, an additional flow of blood is known to be thrown into the brain; and so powerfully does this tend to increase the action of the heart, that it is of the utmost importance to avoid all strong excitement of mind during fevers, and in persons whose health is delicate. By the proper exercise of the mind, the brain is made to increase in size and power;—by long continued idleness, it becomes feeble, and even *dwindles in bulk*. How important is it, then, that we should rightly employ the powers that Providence has bestowed upon us, in order that we may strengthen and increase them! No function can be permanently neglected without subjecting us to a punishment proportionate to the importance of the idle organ.

275. Although the habitual exercise of the function of an organ increases its bulk and strength, and its long continued repose diminishes them, you should not infer that perpetual activity promotes the nutrition of any part. Alternate rest and exertion are necessary to the health of all the organs. Even the heart, though it keeps up a continual circulation, enjoys its period of rest at every pulsation, and it is allowed to do so in the following manner. The right auricle receives its blood from the venæ cavæ at the same moment that the left auricle receives its portion from the pulmonary veins; and during this operation the auricles are relaxed so as to rest themselves from all exertion. At the same moment that these cavities are becoming filled, the two ventricles are in the act of contracting and expelling their contents into the arteries. The instant the latter are emptied, they relax themselves in their turn, and the auricles contract and drive the blood into them. Thus, one half the

heart is always resting while the other half is in action. This is the cause of the double beat that is felt when one places a hand on the heart.

276. When, on long pedestrian journeys, a man exerts himself to great excess in walking, he is observed to grow thinner from day to day, instead of increasing in bulk; because the power of life is mainly directed to his muscles, and his stomach will not act with energy in digesting his food except when they are at rest. If he attempts to eat while using great exertion, or if he uses powerful exercise immediately after a meal, his stomach refuses to digest, and the food, instead of supplying nourishment, becomes altered in character and irritates the organ; so that if he desires to be able to continue his labour or his journey free from dyspepsia or other disease, he must take his meals when he has sufficient time to repose his muscles. As this happens but seldom during pedestrian excursions, he is obliged to live the greater part of the time upon himself (216) which is a sufficient reason for the thinness observed on such occasions. A wise traveller, if he be charitable or even economical, will attend to those circumstances that disturb nutrition at its fountain head—the stomach—not only in his own person, but even in his horse. Fortunately, violent exercise, while it lasts, diminishes the appetite—but after it is over, both the appetite and the rapidity of general nutrition are astonishingly increased. After long journeys both men and horses who have followed a well-regulated course of diet and exertion grow fat and fleshy with surprising speed.

277. Sleep is the natural repose of all the organs. It is perfect in some, but partial in others. When we do not dream, our voluntary muscles and our minds are perfectly at rest; even the tonicity of all the fibres is diminished (116); and although the stomach still acts, if it contains food, it acts feebly and laboriously, and suffers in consequence. Hence the unwholesomeness of late suppers, which are very apt to arouse both the mind and the muscles, in dreams, at the same time that they exhaust the stomach. The nutrition of the organs, absorp-

tion, and secretion continue during sleep, but they are much less active. Even the heart beats more slowly, and the pulse and breathing are less frequent. You can readily understand, then, how seriously the loss of a proper proportion of sleep must affect the health of animals; for it not only disturbs nutrition by exhausting all the organs by which that process is effected, but it fatigues also the muscles and the brain. Muscular and general debility, weakness of mind, and even insanity, may be produced by it. The more all the organs of the body are employed, the more repose they require; and as the organs of a child are busy with their own growth, in addition to their proper functions, a child requires much more sleep than an adult. In old age, as you will learn presently, the nutrition of the body becomes less active, and all the apparatus of nutrition—the stomach, lacteals, heart, and blood-vessels—move more slowly. In addition to this, the muscles become feeble, and are less employed. Hence old persons require much less sleep than even those in middle life. Cruel suffering and loss of health to children and servants often result from an ignorance of this principle; but let not this fact be advanced as an apology for improper indulgence; for an excess of sleep is sure to produce feebleness of mind and body by preventing the proper exercise of the functions.

278. An exertion of any organ beyond its powers induces weakness that disturbs the nutrition of the organ for a considerable time; and it recovers its energy more slowly in proportion to the excess of its exertion. When this is extremely violent, the function of the organ may be totally and permanently destroyed. We sometimes see palsy produced in a muscle, simply by the effort to raise too great a weight. The sight is impaired, and total blindness may be produced by exposure to a light too strong or too constant. The mind may be deranged, or idiocy may follow the excess of study or the overtaking of the brain. I have actually witnessed all these results and many others of a similar character. Now when the function of an organ is permanently impaired or destroyed by over exertion, the nutrition of

the part is rendered insufficient, or is entirely arrested; and then the absorbents remove it wholly or partially, as they do every thing that is no longer useful. Thus, in palsied patients, a few years after the attack, we often find scarce any trace of the palsied muscles remaining; they are reduced almost to simple cellular tissue. The condition of the calf of the leg in persons with club-foot is a familiar proof of this.

279. In some countries, and in some professions, multitudes of unfortunate children or slaves are compelled to labour daily without sufficient food or sleep, and with scarce any rest after their meals. These miserable beings are also deprived of proper exercises for the mind, while their voluntary muscles are continually overtasked. Can you wonder, then, that all these causes of disturbance to nutrition should render them feeble, sickly, often deformed, and generally imbecile? Such cases are yet rare in our happy country; but the time is fast approaching when the ignorance of physiological laws in masters and employers, together with the increasing demands of luxury and avarice in a crowded population, must render them common. May I not hope that your reflections upon the general principles here laid down will render you useful in checking such horrors when your age and social position shall have extended your sphere of influence?

280. The process of assimilation (47, 48),—commenced in the alimentary canal by the formation of the chyme, continued in the lacteals by the perfection of the chyle, and still further perfected in the lungs when the chyle is carried into them mingled with the venous blood* (197) — is not brought to perfection until the particles selected from

* We know not what change is produced in the chyle by respiration after it has mingled with the blood in the veins of the general circulatory system and has been driven with that fluid into the respiratory organs; but we *do know* that it can be traced no farther than the pulmonary capillaries. It is not to be found in the arterial blood. Some physiologists believe that more oxygen is absorbed in the lungs than is necessary to form the carbonic acid that is expired. If so, this surplus oxygen may be united with the chyle to convert it into arterial blood. But this subject has not been sufficiently examined.

the blood are actually combined with the substance of the body which they are designed to nourish. Now, you have been told that each organ has its peculiar mode of life, and selects for itself the particles necessary for its growth and sustenance. The organs themselves are therefore to be regarded as agents in effecting the nutrition of the frame, and it is in them that the process of assimilation is completed.

CHAPTER VIII.

ON THE NERVOUS SYSTEM.

281. You have now made sufficient progress in your studies to perceive how various and complex are many of the motions necessary to maintain the life of an animal of an elevated rank in the scale of nature. You have seen this very strongly exemplified in the history of nutrition, for the accomplishment of which function the alimentary canal is called into action in order to digest the food, and to pass the chyme forwards so as to be gradually subjected to absorption; the lacteals, to convey the chyle to the blood-vessels; the right side of the heart, to drive it into the respiratory organs; the respiratory organs, to convert it into arterial blood; the left side of the heart to drive this blood through the aorta, &c.; and finally, the various organs themselves come into play in order that each may select from the blood the sustenance that it requires. Nutrition being once completed, absorption soon commences; the lymphatics and the veins convey the worn-out particles of the frame back into the circulation; and the respiratory organs and secretory glands begin the process of purification, that the breath and the ducts of the glands may discharge from the body the particles that are unfit for the purposes of life. These complex motions cannot be performed in an irregular manner. They must succeed

each other in proper order in propelling every particle to its proper destination, or life would be sacrificed in the more complex classes of animals, almost at the moment of its commencement. There is therefore a mutual dependence of all portions of the machinery of organic life (101) upon each other, and a necessity for some medium of communication from one organ to another by which they may convey mutual information of their several conditions, if I may be permitted to employ a figurative expression. Were there no such medium, how would the stomach notify the heart that additional exertion on its part is required, because the stomach is busy in digesting food (274)? When we are exerting our muscles for a long time together in some laborious employment, how else are our members to inform the stomach that they are too much occupied with their duties to spare the blood necessary in digestion, that it is requisite that the appetite should decline, and that digestion should cease for the time, even if the stomach should be oppressed with its contents (276)? When we are thinking, how else are the blood-vessels to be told that an unusual supply of their contents is wanting in the head (274)? or when the whole frame is weary with exertion, how, without some regular line of intelligence between the various organs, is the brain to be instructed that circumstances require that it should go to sleep (277)? To supply the necessary medium of communication, Providence has furnished all the animals that possess distinct organs with a peculiar apparatus called *the nervous system*.

282. In the simplest animals, that are not provided with any obvious organs, we discover nothing resembling the nerves: but even in the most minute and apparently unimportant beings that have any trace of a circulation or muscular system, something like the rudiments of a nervous system are perceptible. At first we detect nothing of the kind except a few faint white lines running from one organ to another through the transparent substance of which these animals are formed: and it is only among such as are a little more elevated

in the scale of nature that we can usefully study the structure of this singular system. It is best understood from an examination of the anatomy of the quadrupeds and man; and when we speak of the materials that compose the nerves in those animals that have no internal skeleton, we are compelled sometimes to reason from analogy rather than from actual observation.

283. Thus examined, the matter constituting the nervous system appears to be composed of two substances very strongly resembling each other, but differing in colour and in the arrangement of the particles. The first of these substances is called *the cineritious matter* of the nervous system, from its colour, which is ash-gray or reddish. When examined under the microscope, it appears to be formed of minute globules collected together without any particular order. The second is called *medullary matter*. It is of a clear white or pearly colour, and the globules of which it is composed seem to be ranged in regular rows so as to form fibres or *filaments* of great length and extreme delicacy.

284. In those animals that are provided with a brain, properly so called,—that is, in all animals that have an internal skeleton,—this most important part of the frame is composed of a large amount of both these substances, penetrated by innumerable minute capillaries; as are all the organs in the body, except, perhaps, the articular cartilages. The cineritious matter is placed, for the most part, on the outer surface of the brain, whence it is often called *cortical substance*, and the central portions are chiefly composed of medullary matter. It is observed that every filament of this medullary matter originates at one extremity in the cineritious or cortical substance, and the latter owes its red colour to the greater size and number of its capillaries.

285. The cellular tissue in which the cineritious and medullary matter are deposited is so extremely delicate that it cannot be detected during health; and its existence has been denied by some physiologists, who have considered the nervous system as an apparatus constructed on different principles from the other organs of

the body; but in certain diseased conditions, the cellular membrane of the brain becomes very distinct. Some cavillers insist that in these cases the membrane is formed by the disease, and does not exist in the healthy brain; but I have recently met an instance in which it was so thickened and hardened in one spot by an injury of the head, that several ounces of cortical and medullary matter were seen completely enclosed in distinct cellular tissue as strong as that which surrounds and penetrates the muscles (149): thus giving undeniable proof of the beautiful simplicity of the natural laws that govern the formation of all organized bodies without exception.

286. The consistence of the nervous matter of the brain is scarcely greater than that of curdled cream or the softest cream-cheese, but it is always enclosed in a bony case that protects its most delicate structure from injury.

287. Besides the brain, there are many other collections of medullary and cineritious matter formed into small masses, and scattered throughout the body. These are called *ganglia*, and each *ganglion* is considered by some physiologists as a little independent brain, ruling over some of the organs in the same manner that the true brain seems to do over the frame in general.

288. The brain and ganglia are two most important parts of the nervous system, and each little row of globules of medullary matter which they contain (283), may be regarded as a *nervous filament*; yet these organs are not commonly called *nerves*; that name being reserved for another portion of the system which will be presently described: they are often called *nervous centres*. At one extremity, each of the nerves in the body is connected either with the brain or a ganglion, from whence it runs to be distributed to some distant part. It is the special function of each of the nervous centres to receive information by means of certain nerves, of what is passing in that portion of the frame over which it presides, and to issue through certain other nerves, the orders necessary to regulate the action of all the organs of the body accordingly.

289. A nerve is a bundle of medullary filaments (283) collected into a cord passing from the brain or from a ganglion to some distant portion of the body, the functions of which are subject to its control. At fig. 36 you see the representation of

a portion of a very large nerve with its fibres or filaments, one of which has been drawn out by a pin. The whole cord is always covered by a

strong sheath of cellular tissue strengthened with fibres, forming a membrane called the *neurilema* or nervous coat, which would resemble a tube were all the filaments removed; and each particular fibre is enclosed in an extremely delicate sheath of the same kind of membrane. In this respect the nerves are arranged like the muscles (146). In fig. 36, the thick membranous covering conceals the filaments, so that their divided extremities alone are visible.

290. Each nervous filament has its own especial destination, and is believed not to be united with other filaments in any part of its course. It has also its own peculiar function, and may act independently of those with which it is associated. A nerve is, therefore, a bundle of organs rather than a single organ.

291. In the primary nervous trunks, where they first come out from the substance of the nervous centres, all the filaments appear to possess similar, though not perfectly identical functions. Thus, one cord is composed of filaments, all of which are acutely sensitive to the *touch*, while another employs all its fibres in controlling the *motions* of the parts to which it is distributed. If you divide the former, you destroy all sensation or feeling in the part to which the nerve is distributed, though its motions may continue. Thus we see certain cases of palsy, in which the patient cannot feel the slightest pain in an arm or a leg when pricked by a pin or injured in any other way, and yet he continues to use the member as when in health. If, on the contrary, we

Fig. 36.

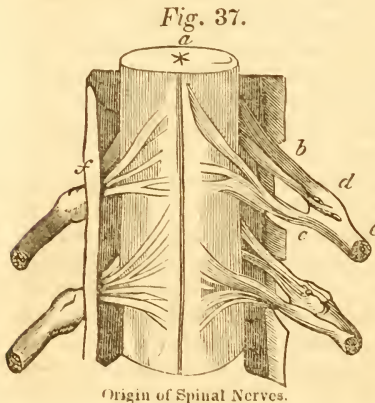


A portion of nerve.

divide one of the latter class of trunks, all power of motion ceases in the parts supplied by it, but the sensation or feeling remains. Thus, there are cases in which the limbs are palsied and rendered totally useless, yet continue to feel, and may even be the seat of severe pain induced by disease. You must divide or injure both trunks, or the filaments arising from them, before you can destroy the functions of both muscular motion and feeling.

292. But few of the nervous trunks travel far from their origin in the nervous centre to which they belong before they send off some filaments to associate themselves with other trunks whose functions are of a different character from their own. From the combination of these different sets of fibres new nervous cords are formed. Each fibre of these compound cords retains the same function that it exercised in the parent or original trunk to which it previously belonged, but the whole nerve, resulting from the assemblage of fibres from different sources, enjoys all the functions of the different trunks that send branches to assist in forming it. As one of these secondary nerves approaches the parts with which it is designed to communicate, it transmits to them branches or bundles of fibres, most

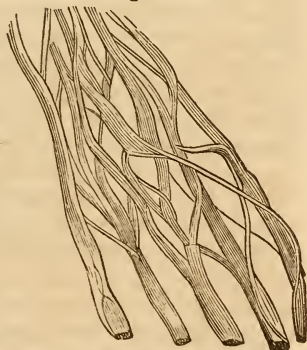
of which contain filaments from all the parent trunks, but at length these filaments are separated from each other, and each conveys to its final destination the same powers that it possessed when it first left its nervous centre. Let me give you an example. In fig. 37 you see a representation of the origin of four of the



nerves of feeling, and four of the nerves of motion in man: these all originate from the spinal marrow—a nervous centre closely associated with the brain, and occupying a canal formed by the bones of the back, as will be explained in the after part of this volume: *a* is the spinal marrow; *f*, the membranes lining the canal in which it is placed; *b* is the original trunk of a nerve of feeling, commencing from the spinal marrow by many little bundles of filaments with similar functions, and united into one cord at *d*. If you cut this cord, all feeling will be instantly destroyed in those parts of the body to which these filaments are distributed, but the power of muscular motion will remain. At *c*, is seen the original trunk of the nerve of motion, designed to supply the same parts of the body. It originates from the spinal marrow in a similar manner, and its filaments are also collected into one cord at *c*. If you divide it, all power of muscular motion in the parts supplied by its filaments is immediately lost, but feeling still continues. All the filaments from both these original trunks are soon collected into one bundle instead of two, so as to form a single resulting nerve, *e*, that commands both motion and feeling—if, then, you divide this compound nerve, both feeling and motion must cease in all the parts to which a fibre of either of the original trunks is distributed.

293. It is not uncommon for a considerable number of nerves to intermingle their branches, so as to form a nervous network, giving rise to a number of new cords, or distinct nerves; so that the original trunks from which the filaments are derived seem to be lost in the labyrinth into which they are thrown. Such a network is called a *plexus*, and one of these is represented at fig. 38. You

Fig. 38.



A Nervous Plexus.

can readily judge how complex the function of a nerve originating from a plexus may be rendered; but each fibre generally retains its own powers unaltered; and the plexus cannot be regarded as a proper nervous centre.

294. The *ganglia* or true nervous centres are scattered throughout many parts of the nervous system, and generally they appear as if formed by the enlargement of one or more nerves, which do not appear to terminate in them, but pass through them on their way to their ultimate destination. The number of nervous trunks that enter a ganglion on one side is often less than the number that pass out on the other; but the latter, taken collectively, are almost always larger than the former. This seems to show that some matter must be added to the nerves as they pass the ganglia.

295. It is believed that all the filaments of the original trunks entering these organs continue their route without interruption to the resulting branches that leave them. But *their filaments*, while within the ganglion, are deprived of their cellular sheath or neurilema (289), so that they are reduced to nearly the same condition with the fibres of the brain (288), and are brought into contact with the cineritious matter that forms part of the bulk of a true ganglion. The filaments are wound round each other in the most complex manner; so that they are traced with extreme difficulty; but it is believed that every nerve passing out of a ganglion contains fibres derived from each of the trunks that enter it.

296. The intermingling of the nervous matter in the ganglion is much more intimate than that which takes place in the plexus; and the very functions of the filaments seem to be changed or modified by this close association. It is also believed that new fibres originating from the cineritious matter of the ganglion are added to each resulting nerve.

297. You have learned, in the earliest part of this work, the following facts: 1st, That the simplest animals, apparently composed of cellular tissue alone, and unprovided with any special organs, are capable of digesting their food without any special organs of di-

gestion; but that animals of more complex organization require a peculiar apparatus to accomplish the same function. You have learned also that the former animals can drive their nutritive fluid, or blood, from place to place, so as to nourish all the parts of their frame, by the mere contraction of the cellular tissue; but that the latter have need of a circulatory apparatus, and capillary vessels to effect this purpose. Among those animals which rank still higher in the scale of nature, you have been told that another class of vessels—the absorbents—become necessary to assist in the process of nutrition. The simplest animals secrete without glands and respire without respiratory organs, perform locomotion without muscles, and exercise a will without visible nerves or brain; but those of more elevated character require the aid of complete systems of distinct organs for each of these vital operations. You must have observed, moreover, that all the organs in these several systems, whatever their special function may be, demand the presence of capillary blood-vessels to carry nourishment into them and absorbents to bear away their worn-out particles. Blood-vessels and absorbents, therefore, form a part of every organ in the body. This is easily proved by filling the arteries of an animal with a coloured injection, which will be found to enter freely every organ except the tendons, ligaments, articular cartilages, and the cuticle with its appendages, (such as hair, horn, nails, the enamel of the teeth, shells, &c.) Even in all these, except the two last, the existence of vessels too minute to receive injections may be inferred with much fairness from the history of their diseases. The structure of the articular cartilages is not yet clearly understood, and the cuticle with its appendages is merely an inanimate crust upon the surface of the body.

298. Not only the nutrition, but the special functions of every organ, other than those just excepted (297), are dependent upon the presence of the blood-vessels. In the more complex animals and man, the stomach cannot digest, the lungs cannot respire, the glands cannot

secrete, the skin cannot perspire, without the aid of the capillaries furnished to them for the purpose ; and sometimes these capillaries are distinct from those that convey nourishment to the same parts ; as is the case in the lungs (259).

299. Now every organ, with the same exception (297), is believed to be supplied with its appropriate nerves from some nervous centre, which enter into its structure and form a part of it ; and these nerves are just as necessary, both to its nutrition and to its function, as are the blood-vessels themselves. If we cut one cord, the heart soon ceases to act ; if another, the stomach loses its power of digestion, and the lungs fail to separate the carbon from the blood, &c. ; so that every stage of nutrition, in the more complex animals—the circulation, absorption, secretion, and respiration—are under the control of the nervous influence ; and you have been informed already that feeling and muscular motion are destroyed by the division of the fibres on which they depend. The same is true with regard to the senses of sight, hearing, taste, and smell, each of which may be lost for ever by an injury to the nerve that supplies the organ whose function it is to convey the impressions made upon those senses.

300. Now the whole nervous system may be divided for convenience into several portions, according to the classes of the functions over which each group of nerves, or nervous centres, is found to preside : and the term *system*, in a more restricted sense, has been applied to the two primary divisions of this great system. Thus, when we speak of those nerves and nervous centres that preside over the circulatory, digestive, secretory, and other apparatus of organic life, we term them collectively *the nervous system of organic life* : and when we speak of those nerves and nervous centres that control the five senses and the locomotive apparatus, we term them *the nervous system of animal life*. It is needless to explain what is meant by the names applied to the lesser groups of nerves, such as the respiratory nerves,

the nerves of feeling, the motor nerves, &c., for these names are indicative of the functions performed by the organs which they designate.

301. The nerves of organic life are very irregular in their course. Nearly all the ganglia in the body belong to this class of nerves, and they are all bound together into one system by branches passing from one ganglion to another. They are placed, for the most part, in the great cavities of the body that contain the lungs, heart, great blood-vessels, the stomach, intestines, liver, &c.; that is, they are located among the great organs of animal life, whose functions are governed by them. Their minute branches travel with the blood-vessels all over the body, to regulate the circulation, nutrition, and the secretions of the secretory glands.

302. It is a curious fact, that all the organs governed by this system are, like the nerves themselves, irregular, and never arranged in exact pairs on opposite sides of the body, like the organs of animal life. The blood-vessels in the extremities of the larger animals do indeed appear to be arranged in corresponding couples on opposite sides of the body, but this appearance results entirely from the necessity of the case. A man has two arms, each containing similar organs to be nourished, and each arm is provided with its proper great artery, but if we trace these arteries to their origin from the aorta, we find them altogether unlike in their commencement. The artery of the left arm arises directly from the aorta, while that of the right arm springs from a great branch of the aorta, at some distance from this latter vessel. In like manner, if we compare the minute arteries, the capillaries, or the small veins of the two arms, they will be found to present, in a remarkable degree, that irregularity which is attached to every thing connected with organic life.

303. On the contrary, the nerves of animal life are remarkably regular, being disposed in corresponding pairs, that take their rise in the brain or spinal marrow, and are distributed to the correspondent organs on each side of the body; for all the organs of animal life, in-

cluding the osseous and muscular systems and the organs of sense, are ranged in equal and very similar pairs on opposite sides of the body, like the arms and the legs. Even the brain and spinal marrow, which are portions of the nervous system of animal life, are composed of two opposite portions very similar to each other, but united together in the middle so as to resemble single organs.

304. You must not infer, from what has been stated, that these two nervous systems are unconnected with each other. Along each side of the spine,—that bony column of the back found in all animals possessed of an internal skeleton,—and on the front or anterior face of this column, we find a row of ganglia nearly as numerous as the separate bones into which the spine is divided. These ganglia are connected together by nervous cords throughout their entire series, and some filaments from the upper members of the series even enter the cavity of the head that contains the brain. The whole range of the nervous centres just mentioned, together with all their connecting cords, is called *the great sympathetic*, or *intercostal nerve*, though, in fact, it is rather a system than a single nerve. It gives origin to the principal nervous filaments that are distributed to the intestines; and also contributes to the formation of the nerves that supply the lungs, heart, and stomach. In addition to its direct connexion with the brain by means of the filaments that enter the cavity of the head, it has numerous connexions by means of branches with the nerves of motion and feeling as they come off from the spinal marrow (292). Thus this great nerve unites the system of organic life with that of animal life, and binds into one entire system all the nerves of the body.

305. But you have been told that the functions of organic life are carried on without the consciousness of the animal (136, 137); and this could not be the case if the perceptive nerves of the organic system were capable of the sense of feeling, or if the motor nerves of the same system were subject to the control of the will. For this reason, the impressions made on such nerves, in

all animals that have an internal skeleton, are very imperfectly felt by the brain, in which is seated the consciousness and the will of these animals. Still, as there are numerous connexions between the ganglia of the sympathetic nerves and the apparatus of feeling or touch, that of voluntary motion, and the brain (304), you can very well understand how, during health, the vague sensation of hunger may be communicated to the brain, so as to stimulate us to procure food as it becomes necessary, and how a uniform feeling of comfort and contentment should be spread over mind and body by the just and proper gratification of all the purely physical wants of our nature.

306. In diseases of the system of organic life, it is necessary that the powers of locomotion should be prevented from acting with energy, or the bodily disturbance resulting from the exercise of the organs of animal life would be likely to render the disease worse, or to check the efforts that the organs always make for the purpose of correcting the disorder under which they labour. Very wisely, then, is it ordered that the connexion between the two nervous systems should enable the organs of animal life to perceive the danger in which those of organic life are placed by disease. Hence the strong desire of rest, the intolerance of light, the weakness of the voluntary muscles, the feebleness of mind, and even the great soreness of the stomach, observed in many fevers which originate in the stomach or intestines.

307. In certain accidents we see still stronger proofs of the mutual influence of the several parts of the nervous system upon each other. I will give you a few examples. A violent irritation of the intestines not unfrequently occasions severe cramps of the muscles, and particularly those of the lower extremities, attended with terrible pain, not in the intestines where the disease commences, but in the limbs themselves. The Asiatic cholera gives you an instance of this kind. Certain poisons are well known to act upon the stomach in such a manner as to produce horrible convulsions, accompanied

by a total loss of consciousness. Mere distention, by over-eating, will sometimes arrest the functions of the brain, as far as mental operations are concerned, without disturbing the nerves of voluntary motion. Any very severe and extensive injury to an organ indispensable to the business of nutrition, will produce a great degree of weakness of the whole nervous system; so that the power of the senses, the mind, the heart's action, the beating of the pulse, the digestion, &c., are all most seriously diminished; and the animal, in great danger, deprived of vital energy, sinks into *collapse*, as it is termed. After a time the vital powers begin to recover their force by resting. The heart commences acting with more vigour, and continues to increase its exertions until they very far exceed the proper standard of health. One organ after another is wakened to more powerful efforts in order to assist in repairing the injury, and the animal is found to labour under a fever, which, unless managed and regulated by art, may exhaust some weakened organ, and thus ultimately destroy life in attempting to restore health. The practice of medicine consists, almost exclusively, in the necessary regulation of these natural consequences of injuries and disease.

308. Now, nearly all the connexions between the nervous systems of organic and animal life are made through the sympathetic nerves and their branches; and of course their connexions are the cause of the associated actions of parts so widely separated as the intestines and the extremities, the stomach and the brain, &c., noticed in the four last paragraphs. These associated actions are due to a cause of the nature of which we know nothing more than we know of the nature of attraction or gravitation. All we know is, that it acts through the nerves and ceases when they are divided. But it is convenient to give some name to this power, and it has been termed *sympathy*, by the common consent of physiologists.

309. When an impression is made upon one of the ganglionic nerves by any thing occurring in the apparatus of organic life, this impression is immediately con-

veyed to the ganglion from which the nerve originates, and the ganglion instantly transmits all necessary nervous influences to the organs under its control. If the importance of the impression demands the aid of other organs, it is conveyed through the branches that connect the different ganglia, so as to rouse them also into action, and then the whole apparatus of organic life may be called into exertion. If still further aid be demanded, the message is forwarded to the brain and spinal marrow, through the sympathetic nerves (304), and we may then even feel pain communicated from the heart, the stomach, the lungs, &c., but the sensation is always vague and its location indistinct.

310. The cases in which the will has been known to cause some slight disturbance of the functions of organic life are rare, though no point in physiology is better understood than that occupation of the mind retards digestion in the same manner with occupation of the muscular system (276), and all of you must have observed how greatly the vital operations are influenced by the play of the passions, which, when very violent, not only injure the health, but may even occasion sudden death—a result that has been known to happen as well from joy as grief. In these cases it is not the brain alone that suffers functional injury, for this would only destroy the reason; but even the heart and stomach are paralysed by their sympathy with the brain; and without the constant action of these organs, life cannot be preserved in any of the more perfect animals.

311. You have now been made acquainted with the close dependence of nutrition upon the circulation, and the necessity of nervous influence to regulate the circulation. You will be little surprised to learn, then, that the functions of the nerves themselves, like those of all other organs, depend upon the supply of blood furnished to them by their capillaries. This dependence is strictly mutual; for, if we prevent the blood from flowing towards any particular nerve, it loses its power of receiving or conveying impressions, and the parts to which its filaments are distributed become numb and cold by the

destruction of their functions. On the other hand, if we could remove all the sources of nervous influence from any particular vessel or set of vessels, they would lose their power of carrying on the process of nutrition in the parts to which they supply capillaries, and the same numbness and coldness would occur in those parts, by the arrest of their proper nourishment.

312. Thus you see that all parts of the frame are linked together by bonds that cannot be broken with impunity. Even man, with all his wonderful complexity of organization, his thousands and tens of thousands of vessels, his multitudinous machinery belonging to so many different systems, his acute senses, his high feelings and far-stretching powers of thought, which require, in this state of existence, the aid of the most delicate organs, constitutes but one complete machine, of which no link, no cord can be disturbed without results that are felt in every fibre. In whatever portions of the frame the faint beginnings of disease may be perceived, the actions that may result from it are capable of being extended throughout the body; and so nicely balanced is this mysterious being as it comes from the hand of the Creator, that

“When obedient nature knows his will,
A fly, a grapestone, or a hair may kill!”

Is it not, then, wise in us to seek diligently for the little knowledge of this our fragile tenement which Providence has placed within reach of our understanding—a tenement liable to perpetual accidents, and alike threatened with injury or destruction from an imprudent indulgence of our physical desires or an unguarded burst of mental feeling?

313. In most of the foregoing remarks upon the nervous system, I have referred chiefly to the condition of the nerves as observed in those animals that have an internal skeleton. Among the inferior orders that are provided with *external skeletons*, the nervous system appears to be entirely ganglionic, or, in other words, all the nervous centres are ganglia, and there is no organ

that can be very fairly called a brain. It is true that in many, if not most of these creatures, we find several connected ganglia situated about the head, if there be a head, or about the mouth, if there be not; and where there are any traces of special nerves of sight, hearing, taste, or smell in these animals, they are found to originate from these upper ganglia. You will frequently meet with the term *brain* in works upon insects, worms, &c., written by naturalists of distinction. Whenever this is the case, it is well to remember that these writers generally refer to the largest of the superior ganglia just mentioned; but we can discover no similarity of organization between this organ and the true brain of the most perfect animals.

314. When we descend still lower in the scale of nature, even the nervous centres disappear, a few scattered filaments alone remaining; so that there is no nervous *system* properly so called. At length no filaments can be discovered; and though nervous matter is supposed by some writers to exist, even in these last links of animated nature, in the form of detached grains, this is a mere *guess*, and unworthy of serious attention, at least in the present state of science.

315. The arrangement of the nervous system in its simplest forms, among the lowest orders of animals, somewhat resembles that of the nerves of organic life in man; and, as the whole history of animated nature proves that the organic functions are brought to high perfection much earlier in the scale of developement than those of animal life, it may be fairly inferred that these primary forms are really devoted mainly to the regulation of the organic functions, when these functions begin to require specific organs, which is not the case in the hydra and the polypi. Yet all these animals, however simple, give evidence at some period of their existence, that they possess senses, instincts, and volition. These functions, then, which in man and the other higher classes of animals, appear to belong to the nervous system of animal life exclusively, would seem to be exercised by that of organic life in insects, worms, &c.; nor

can we safely deny that they may reside in the mere cellular tissue of the hydra, in which we can discover neither a nervous filament nor a special organ of any kind.

316. From what has just been stated, it is evident that we cannot compare the nervous system of the inferior animals with those of man and the other noble creatures that possess a bony skeleton and a proper brain, with any hope of improving our knowledge of the connexion between the construction of the organs of sense and the brain in the latter, and the functions that these organs perform. If the bee displays an accuracy in the construction of its honey cells, and a beauty of discipline in the government of its little community of industrious labourers almost equal to what is accomplished by man himself with the aid of mathematical science and political philosophy, and if all this be accomplished with the assistance of a slender collection of ganglia and ganglionic nerves, it does not follow that the brain is not the instrument of all the instincts, feeling, and intellect in the lord of the creation, and the centre of all the perceptions that follow the impressions made upon the organs of the five senses. Though this difference of organization has been much insisted on by many who oppose the modern doctrines of physiology on the subject of the functions of the brain, it is capable of a ready and satisfactory answer. If, as you have seen, a polypus can respire by means of its skin alone, while a fish requires gills, and a quadruped lungs, for effecting their more perfect respiration, it surely cannot be very wonderful that an insect should display its instinctive powers, wonderful as they may be, in consequence of the structure of its principal ganglia, though quadrupeds and man require, for the exercise of their far loftier mental endowments, the complex and singularly delicate organ, or system of organs, properly called the brain.

317. The gradual separation of the vital functions—which seem to be all associated at first into one general process of imbibition and transpiration accompanied by

an obscure sense of touch and some traces of will—and the formation of one set of specific apparatus after another, observed as we advance from the hydra up to man, has given rise to the general employment of a term that I have been compelled to use more frequently than I desired. I allude to the *scale or chain of nature*. You might be inclined to suppose, from the obvious tenor of this term, that there was a uniform series of gradual developement observable in all the details of organized beings from the beginning to the end of animated nature. Now, although we certainly perceive a regular gradation in the perfection and energy of the vital functions, when we cast our eye over the whole field of the animal creation, yet we cannot discover the same regularity in the structure of the several organs or systems of organs as we pass from one great class of beings to another. Thus, some insects may be much more complex, or, as we might say, perfect in organization, than some worms, while certain worms may be much more perfect than most insects. The circulatory apparatus of many worms is far more complete than that of insects, while the instincts of many insects vastly surpass those that have been heretofore observed in any worms. The same remarks will apply, though with somewhat less force, to comparisons between birds and quadrupeds, between reptiles and fishes, &c. Providence appears to have formed the animal kingdom upon several different models that cannot be fairly compared with each other: but this is a subject which belongs to that branch of natural history which is termed zoology, rather than to physiology. I notice it here, partly because I may one day offer you a text-book upon zoology, to which this volume may serve as a suitable introduction; and partly to prevent you from wasting time in after years, over the worse than useless reveries of certain wild theorists in physiology who have never felt the force of two memorable lines of Pope the poet:

“Why has not man a microscopic eye?
For this plain reason, man is not a fly.”

318. I trust you are now prepared to enter upon the study of the organization of your own frames, so far as it falls within the purpose of the present volume. I trust that the broad view you have taken of animated nature in general will prove useful in several ways: First; by proving the universality of the physiological laws that should regulate the health, habits, and morals of man: Secondly; by making you familiar with the true meaning of the few technical terms that are necessarily used in the current of our studies: and lastly, by enabling you to comprehend more fully the treatises and essays on anatomical and physiological subjects which you may meet with in the course of your future reading.

CHAPTER IX.

OF THE SURFACES OF THE BODY.

319. WHEN you look at the entire body of a human being, you perceive that it is naturally divided into several portions or regions, associated into one complete frame. Of these divisions, the most striking in importance are the head, the neck, the trunk, the superior extremities, and the inferior extremities.

320. Most of these grand regions are again subdivided into lesser regions, which it is well to name, in order that you may understand the meaning given to some very familiar words used by writers on anatomy and physiology in a sense somewhat different from that in which they are received in ordinary conversation.

321. If you draw a cord or string across the root of the nose, and carry the two ends toward the outer angles of the eyes, round the sides of the head across the openings of the ears, and bring them together at the nape of the neck, it may be considered as dividing the head into two portions. The portion which lies above the

string contains the brain, and those portions of the bones of the skull called *the cranium*, which enclose that all-important part of the nervous system, together with certain muscles or parts of muscles, and the integuments or skin of the head, with its appendages. This portion constitutes *the head proper*, as distinguished from *the face*.

322. All that portion which lies below the string is called *face* by anatomists, and you observe that it does not include the forehead, as, in familiar language, the term usually does.

323. The word *neck* is employed by anatomists in its popular sense.

324. The *trunk* is divided into two great portions, called the *chest* or *thorax*, and the *abdomen*. If you pass your hands all around the body, from the lower end of the breast-bone along the inferior margin of the ribs and directly across the back from the posterior end of the lowest rib on one side to the corresponding point on the other side, you encircle the trunk with a line which separates these two great portions. All the surface that lies above the line belongs to the thorax or chest; all below the line appertains properly to the abdomen.

325. But it has become customary to consider the lower part of the abdomen as a third great division of the trunk, and to give it another name. If you carry your hands down the sides of the body, from the margin of the ribs along what are usually called the flanks, you soon perceive that the lower part of the trunk is enclosed, beneath the skin and other superficial parts, by solid bones. The names and general form of these bones you will learn hereafter, but their extent and outline are sufficiently plain. That part of the trunk which is included within these bones is called the *pelvis*.

326. The chest contains the lungs or breathing apparatus, the heart, some of the great blood-vessels, the canal that conveys the chyle to the blood, and certain other organs accessory to these parts.

327. The abdomen and pelvis are chiefly appro-

priated to the accommodation of the alimentary canal, from the stomach downwards, and the numerous large glands or other organs which contribute to the process of digestion; such as the liver, the pancreas, the spleen, &c. &c.

328. The joints by which the superior extremities are connected with the trunk are called the *shoulder joints*; and the upper end of the bone of the arm, the shoulder-blade, and collar-bone,—which well-known parts contribute to form these joints,—taken together with the muscles or flesh, the skin, &c. covering these bones, are called the *shoulders*.

329. *The arm*, as known to anatomists, is that part of a superior extremity that intervenes between the shoulder-joint and the joint of the elbow. The portion embraced between the latter and the wrist-joints is termed the *fore-arm*.

330. The other divisions of the wrist and hands will be better understood when we consider the structure of the skeleton. The same thing may be said of the foot; and it is unnecessary to specify the remaining portions of the lower extremities, because the terms in common use are applied to these parts without any modification of their meaning.

331. The body, viewed as a whole, may be regarded by the physiologist as a great mass of cellular tissue analogous to that which forms the hydra and the polypi, constituted, in some places, of very large and complete membranous cells; in others, of smaller compartments communicating freely with each other, and, in many situations, strengthened with numerous fibres, so as to form a strong network, or those broad and firm expansions known by the name of fasciæ.

332. But the extensive sphere of action designed to be filled by an animal so important in the scale of creation as is man, demands that he should be furnished with almost innumerable special organs for the performance of particular functions; and to this end the vital powers of many different portions of the cellular tissue are so modified, that in one place the cells become filled

with secreted flesh or muscular matter ; in another, with the peculiar substance composing the nervous fibre, &c.

333. In the earlier part of this little volume you were told that even the hydra had an external covering formed of more dense materials than the soft cellular tissue of which the mass of its body and arms are composed, and this external covering was called the skin of the animal.

334. You were informed, also, that this covering presented the same appearance, and performed the same functions, both on the outside of the body and within the cavity for the reception of its food (61).

335. Now, *man*, owing to the complexity of his structure, requires a covering much less simple than that of a mere polypus or hydra. Accordingly we find his skin composed of several layers, differing widely from each other.

336. The first, or outer layer of the skin, is called the *epidermis*, *cuticle*, or *scarf-skin*. It is an organized membrane, because it resembles nothing that is found among inorganic bodies ; but it does not appear to be endowed with life, for it performs no active function. You see the cuticle raised from the surface when blistering ointments are applied, or when a person has been scalded. It possesses no power of feeling, and you may readily pare it off from the palm of the hand with a penknife. After bathing, considerable portions of it are rolled into little scrolls, and carried away by the towel.

337. When you examine a piece of cuticle detached by a knife or scissors, you find it to resemble a very thin transparent piece of soft horn. In many parts of the body it is extremely thin and delicate ; but in parts designed to bear a great deal of pressure and rough usage, it becomes solid and thick ; as in the palm of the hand, on the heel, the ball of the great toe, &c.

338. You have been already told that the claws, horns, and shelly coverings of animals, are productions or appendages of the cuticle (156). Even man is not without some such means of protection or defence ; and in the nails you see the horny character of cuticle almost

as plainly displayed as it is in the tortoise-shell of which combs are made.

339. The cuticle is a secretion poured out upon the surface of the body by the living parts immediately beneath it. At first it is soft or almost fluid; as you perceive if you examine it when beginning to appear on the surface of a blister after the old cuticle has been cut away; but it is not dissolved by water or by perspiration; and it very soon hardens, like a varnish in drying, over every part of the body.

340. You often hear of the pores of the skin, and perhaps you may think that you actually see them scattered over the back of the hand; but this is a deception. There are no regular orifices to be found in the cuticle; but it is spongy, and thus permits the perspiration to flow through it every where with facility. The unevenness of the cuticle is entirely owing to the irregularities of the other layers of the skin, over which this varnish is spread.

341. There are, indeed, two sets of depressions in the cuticle that resemble holes, though they are not so in reality. The first set is seen very conspicuously about the nose, where they are unusually large. They correspond with as many peculiar sacks, buried or formed in the deeper layer of the skin, and known by the title of *sebaceous follicles*.

342. In order to preserve the skin in a soft and pliable condition, it is necessary that it should be freely supplied with an oily or cheesy matter, and it is the office of the sebaceous follicles to secrete this matter. When it becomes unusually abundant, or unduly hard, it may be pressed out of these little cavities by pinching the part with the thumb and finger, and it is then often mistaken, by the vulgar, for "little worms." When cleanliness is neglected, the contents of the sebaceous follicles collect the particles of dust floating in the air, and produce the appearance of small, black specks upon the face, not always easily removed.

343. But, although these cavities are peculiar secreting organs, somewhat resembling glands (224), the cuticle

is not interrupted in its passage over them, but dips into, and lines the sacs; being rendered very thin and less solid in such situations.

344. The second set of seeming orifices in the cuticle correspond with the hairs that are scattered over the body.

345. The hairs take their root in the inner layer of the skin, far below the general level of the cuticle, and each particular hair grows by a secretion taking place at its lower end, where a special organ, of very curious structure, is provided for this purpose, each one being furnished with its proper capillary blood-vessels, and its own proper branch of a nerve. But the hair itself resembles a tube of horn or cuticle, and the manner in which it is formed does not differ materially from that which produces the epidermis, the nails, and other similar parts.

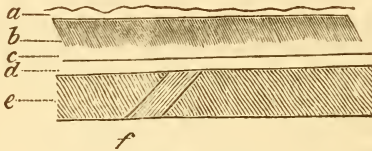
346. As a young hair begins to grow it gradually makes for itself a passage through the thickness of the inner layers of the skin, and at length appears above the surface. But the cuticle dips into this canal from the moment of its completion, and lining it for some distance, as in the case of the mucous follicle, unites with the hair so intimately that no orifice is allowed to exist there.

347. The cavity of the horny tube of the hair is filled with a peculiar substance, secreted by the blood-vessels about its root or bulb, and this secretion shining through the transparent walls, gives the hair the great variety of colour observed in different races and individuals. When age or disease diminishes the vital power of the vessels of the bulb, the internal secretion is often arrested, while the horny matter continues to grow as before. The hair then becomes gray, or silvery white. If the vital power of the bulb be still farther diminished, the horny matter is no longer formed, the hair falls out, the common cuticle grows over the canal, which is soon obliterated, and the part becomes permanently bald.

348. The functions of the cuticle are entirely passive, or mechanical. It protects the delicate and exquisitely sensitive extremities of the nerves of touch from being

injured by the immediate contact of external bodies. It prevents the fluids of the soft parts beneath from being carried off by evaporation too rapidly; and it also prevents the blood in the superficial vessels from being brought so near to the atmospheric air as to be changed in character by spontaneous respiration, which would cause it to prove altogether too stimulating for the purposes of life in such situations. If man could endure the danger, the pain, and the exhaustion of living without a cuticle, he would have no occasion for lungs, and might defy consumption. Fig. 39, *a*.

Fig. 39.



Section of the Skin.

a. The cuticle. *b*. The rete mucosum. *c*. The papillary portion of true skin. *d*. The fibrous portion of true skin. *e*. Cellular tissue beneath the skin. *f*. Some fibres of the fleshy panicle.

349. The cuticle being removed, we next observe the living membrane beneath, which secretes it. This is exceedingly tender; being composed of very delicate cellular tissue, with innumerable capillary blood-vessels winding within it. There is an equally incalculable multitude of the naked and expanded extremities of the nerves of touch or tact passing up from beneath it, so as to render its surface irregular, and produce the corresponding roughnesses observed upon the cuticle.

350. These nervous expansions and their accompanying blood-vessels, which properly belong to a third layer of the integuments, to be presently noticed, are called *papillæ*, and all the nerves of the senses of feeling and taste appear to terminate in this manner. The membrane, or layer of cellular tissue, covering and loosely

connecting these papillæ, is called the *rete mucosum*, or mucous network. It is the middle layer of the skin, and in it is deposited that peculiar colouring matter which gives to each natural or accidental race of men—the red, the white, the olive, and the black—and to each individual, whether brunette or blonde, his own especial hue. Fig. 39, *b*.

351. This colouring matter is probably designed to protect the tender parts beneath from the too powerful action of light, which penetrates the cuticle with great facility. It is found in greater quantity, of a darker hue, and deposited in a thicker membrane, in the animals and men inhabiting the warmer parts of the world; and it is scarcely discoverable in many of those residing near the polar regions. Habitual exposure very gradually deepens the colour on the exposed parts, and there is every reason to believe that the peculiarity thus produced has, like most other individual characteristics, a tendency to become hereditary. Those Hindoos who belong to castes condemned from time immemorial to labour in the burning sunshine and in the open air, are generally found nearly as black as many negroes, while those who have been devoted, for many generations, to the occupations of priesthood and the pursuits of literature, are often paler than the palest American Indians. But these questions of the influence of climate on colour must be regarded as somewhat speculative. The extent of such influence can never be fully ascertained; as ages would be required for the necessary observations, and the effects of other causes of similar changes cannot be fairly estimated.

352. The colouring matter of the hair and the eye is probably of the same nature with that of the skin; and it is observed that the inhabitants of the higher latitudes are almost universally remarkable for their light hair and light blue eyes. The quadrupeds and even the fishes of the polar circle give evidence of the truth of this general rule. The common bear and the ermine of those regions are entirely white. A species of the dolphin of the same colourless character is also

seen in the antarctic regions; and the birds of those regions have generally a white or very light blue plumage, with a skin of a corresponding pale colour. Even in milder climates, one of the hares and a ferret are found to be covered with black fur in the summer and white in the winter.

353. The third and inner coat of the skin is called *cutis vera* or true skin. *Fig. 39. c, d.* By many anatomists it is supposed to be composed of two distinct layers, the outer of which they term the *papillary body* (350), seen in the figure at *c*. But this multiplication of membranes almost artificially, though sometimes useful to the profound physiologist, tends only to confuse the learner. I shall therefore consider the true skin and the papillary body as a single layer.

354. The true skin is composed chiefly of dense cellular membrane, strengthened by very strong fibres, and penetrated by innumerable capillary blood-vessels and nerves. The network of fibrous matter forming the principal part of this membrane leaves very numerous irregularly conical openings between the meshes; through which the extremities of the fibres of the nerves of feeling, each with its accompanying capillary arteries and veins, pass out to the external surface of the membrane, in order to form the papillary body. These conical cavities are comparatively wide on the inner side of the skin, but become very narrow before they reach the outer surface. They are filled with loose and very delicate cellular membrane, binding together the capillary blood-vessels and nerves while allowing the former sufficient freedom of action.

355. On the outer surface of the true skin, immediately beneath the mucous layer, the nervous fibres terminate in an expansion of soft and pulpy nervous matter, supposed by many to consist of cineritious matter (283) and surrounded by an inconceivably delicate network of capillaries. The little eminences thus formed are the papillæ of the skin (350), and in them resides the sense of touch in the highest degree of refinement. When inflammation attacks the true skin,

the papillæ are often subjected to extreme pain, from the swelling of the contents of the little fibrous cones while the fibres cannot enlarge themselves sufficiently to accommodate their increased bulk. The commencement of the mortification that attends upon a carbuncle is occasioned by the swelling becoming so great that the pressure of the fibres closes the capillary vessels as they pass through the true skin, and thus destroys the life of at least the outer portion of the membrane.

356. The root of every hair is seated upon a little organ called the bulb, which is constructed somewhat like a gland, being supplied with its proper blood-vessels and nerve. This organ secretes the hair, by adding layer after layer to the horny matter at its base, and perpetually thrusting outward the older portions. The bulbs of the hairs are seated in the innermost portion of the true skin, and often project below the general level of the membrane into the cellular tissue beneath, so that many physiologists regard the hairs as originating altogether within the skin. This position is evidently incorrect; for when the true skin is raised by an accident, the hair invariably comes with it, without any injury to the bulbs. The latter are therefore included in the true skin which forms little extensions or *processes* inward from its surface, in order to include them.

357. All the essential active functions of the skin appear to be performed chiefly, if not entirely, by the outer surface of the true skin. The vessels of this part supply the materials for perspiration and those also of which the cuticle is constructed. The nerves of the skin, as has been stated, are the principal seat of the sense of touch. When that sense is exercised, or when irritants of any kind excite pain in the part, there is an instantaneous rush of blood to the capillaries, and the papillæ are enlarged and rendered much more sensitive. From the influence of cold, or certain affections of the nervous system that produce the sensation of cold, the cellular tissue of the true skin is made to contract. The papillæ then become very prominent, and give rise to the appearance called *goose-flesh*; but the blood-vessels being compressed by

the contracted tissue, the sensibility of the nerves is diminished.

358. Many quadrupeds and other animals have an additional layer or fourth coat of the skin, called *the fleshy pannicle*, consisting of light-coloured long muscular fibres, originating from one part of the cutis vera, and inserted into another part. The principal function of these fibres is to shake or agitate the skin so as to drive away insects, and to rid the animal of other annoyances. They are so powerful in the elephant, that he is able, by their means, to throw an unskilful rider who ventures to seat himself on the back instead of the neck.

359. These muscular fibres are often connected with the bulbs of the hairs or feathers in certain parts of the body; and this will explain to you the power of dogs, cats, hogs, the eagle, and many crested birds, to erect their manes or feathers when angry. All birds appear thus to elevate their feathers when bathing themselves.

360. In man, this muscular coat is seen only in a few particular parts of the body; as about the neck; but enough is preserved to show the beautiful simplicity of plan displayed throughout the animate creation, and to explain some points in relation to the interior structure of the frame not otherwise so clearly intelligible; as, presently, we shall have occasion to perceive.

361. To prevent the confusion likely to result from the generic term skin, as applied in popular language to the assemblage of all the layers of which we have been speaking, while, by the physiologist, it is commonly confined specifically to the cutis vera* (353), I shall substitute the word *integuments* hereafter, when speaking of the various coverings of the body already described.

* We meet with many tolerably well educated people, who seem through life to have a very imperfect idea of the distinction between a genus and a species, which ignorance is the more excusable because their dictionaries will rarely be found to communicate a clear idea of the subject. If the pupil will endeavour to acquire this knowledge from his preceptor or parent, he will find it useful on many other occasions than the present.

362. The various membranes, layers, or coats composing the integuments, are not placed loosely over each other, but, with the exception of the cuticle or epidermis, they are bound so firmly together by the common cellular tissue,—which, as you have been told, penetrates and constructs all parts of the body (165),—that they appear like a single cloak or envelope, varying from one-sixteenth to three-sixteenths of an inch or more in thickness, and covering all the outside of the person. When you divide them, you find it much more easy to raise them bodily or strip them off from the parts beneath, than to dissect the different coats of which they are composed, one from another.

363. The integuments of the surface of the body are connected with the fasciæ or muscles over which they are placed by more or less of the common cellular membrane, which is very loose in most places, permitting them to slide freely and to a considerable extent. But on the soles of the feet, in the palms of the hands, along the middle line of the back, and some other places, the tissue is strengthened by numerous fibres, and the skin is very firmly bound down to the parts within it.

364. In persons improperly called *fleshy*, the fat to which they owe their bulk is principally deposited in this sub-cutaneous cellular tissue, but it cannot accumulate in great quantities where the skin adheres in the manner described in the last paragraph. Could it do so, the hands and feet might become entirely useless by their bulk.

365. All the internal passages of the body communicating with the surface, even to the last branch of the ducts that convey the several secretions to their destination, are lined or formed by the integuments. And to give you a clearer idea of this fact, I will describe the arrangement of these membranes after they enter the mouth and nose to form the alimentary canal.

366. At the mouth and nose, the external integuments are reverted inwards, so as to cover every part of the walls of these cavities; but the blood-vessels of the true

skin forming these walls become larger, while the cuticle diminishes in thickness and increases in transparency until the blood in the capillaries shines through, giving to the lip its beautiful colour, and to the tongue and throat a still deeper tint. This delicate cuticle now takes the name of *epithelium*, though there is no good reason for this multiplication of terms.

367. The follicles of the skin, which are here more numerous and often much larger than they are externally, secrete mucus instead of the sebaceous matter poured out upon the common cuticle. The true skin is considerably modified also; but notwithstanding these apparent changes, the internal integuments are merely extensions of those already described externally.

368. Immediately behind the nose and mouth, the integuments form a large sac, into which both these passages open. It is called the *pharynx*, and terminates below in an irregular funnel continued into the canal by which the food is conveyed to the stomach. Outside of the mucous membrane corresponding with the rete mucosum, we find a layer of firm and somewhat fibrous cellular tissue answering to the true skin: and enveloping this, we observe the fleshy panicle (358) very much developed, forming three strong muscles, which overlap each other, and are capable of contracting so as to diminish the size of the pharynx, and force its contents downwards into the canal leading to the stomach, called the *œsophagus*. The fibres of this muscular coat are found running in several different directions around the sides and back of the pharynx until you descend to the commencement of the *œsophagus*. They are then chiefly arranged in the circular and longitudinal directions, so that they can compress or shorten the canal as the motions of the food require it to be altered in form. As soon as the *œsophagus* (thus composed of the epithelium, the mucous membrane, the cellular coat, and the muscular coat,) has passed through the chest (324) and enters the abdomen, it expands itself into a large, irregular bag, called the

stomach; from the lower end of which the alimentary canal is continued in a manner to be described hereafter.

369. After the epithelium has lined the inner side of the œsophagus and entered the stomach, it ceases suddenly at the upper end of that organ; and the mucous coat becomes the lining membrane throughout the remaining portion of the alimentary canal.

370. It is impossible to conceive of any thing more delicate than the incalculably fine network of capillary vessels that penetrate most portions of the mucous coat. They are so fine, and approach so near the surface, that when filled with glue mingled with vermilion, after death, the surface appears uniformly red. I have even seen the glue flowing through the sides of the vessels and the membrane into the canal, completely strained and colourless; not a particle of the vermilion being able to accompany it. This will explain the ease with which the blood-vessels can pour out the secreted mucus that lines the alimentary canal, and also, the facility with which the lacteals originating on this surface can select the chyme from the mass of food as it passes.

371. The manner in which the fibres of the nerves of organic life terminate upon the mucous membrane is less understood than that observed in the nerves of feeling beneath the rete mucosum (355); but in those parts of the alimentary canal in which absorption is carried on most rapidly, the whole surface of the membrane is covered with little hair-like appendages composed of capillary veins, arteries, absorbents, and probably nerves. These are called villi, because they give the surface the appearance of velvet. They correspond with the papillæ of the skin.

372. Among the villi and on other parts of the membrane we discover the orifices of innumerable small mucous follicles, and these are collected together in large groups in certain parts of the canal where, from their peculiar structure, they have been termed *glands* and have received special names. But, though a knowledge of the history of these organs is all important to the physician, it is needless to describe them here.

373. You now perceive that the integuments, though possessing every where the same general character, have a much more complex organization in some places than in others. Yet we find throughout their whole extent, whether viewed internally or externally, the two principal layers—the dense cellular layer like the true skin, and the mucous layer, like the rete mucosum. The other two layers appear only occasionally, where they are wanted,—the cuticle principally on the outer surface, as a protection to the delicate papillæ and for other purposes, and the muscular coat chiefly around the alimentary canal, to urge forward the food as the process of digestion advances.

374. The integuments thus constructed penetrate into, or rather they *form*, every little duct communicating with the internal surface of the body. Thus, the gall duct is constructed by the integuments of the small intestine just below the stomach. They here extend themselves into a long canal leading to the liver. On the outside of this organ, the canal expands itself into a sac, called the gall bladder, which receives and retains the bile until it is wanted to promote digestion. At a short distance below the neck of this sac, the duct sends off a large branch which passes into the substance of the liver, and divides there again and again until its capillary branches reach every part of the organ, to convey thence the peculiar secretion of this enormous gland. Throughout its entire course, the gall duct is constructed on the same general principle with other parts of the integuments; but it has a muscular coat only where this is necessary for the purpose of promoting or checking the flow of bile towards the intestine. Behind the root of the tongue, and before the commencement of the œsophagus, is placed the upper extremity of the organ of the voice, called the *larynx*, Fig. 32, 1, page 123, which admits the air into the trachea. It opens into the pharynx by a narrow orifice, of which I shall speak more fully hereafter. Now, when the integuments of the mouth and the pharynx reach this orifice, they enter

it, (becoming somewhat modified in their organization,) and line the inside of the trachea and bronchiæ even to the air-cells of the lungs. From the cavity of the nose the integuments extend themselves through a passage in the bones of the face, and form a canal for conveying the tears from the eye. This canal has also its sac or expansion near the upper extremity. But it is needless to quote more instances in illustration of the general principle that all passages communicating with the surface are formed by the integuments, and bear a close resemblance to the skin.

375. Even when disease produces an opening communicating with the skin, if it be narrow and does not heal for a long time, the vital powers at length cover it with integuments which sooner or later present the appearance of the mucous membrane, and the canal becomes converted into a part of the surface. Such passages are called fistulæ. They are sometimes produced artificially by the surgeon for the cure of more formidable diseases. To give you a clearer idea of this, I will mention an operation by which a very disagreeable consequence of certain wounds of the face has been occasionally cured. The principal gland that secretes the saliva poured into the mouth is placed over and behind the lower jaw, near the ear. Its duct runs forward towards the middle of the cheek, and there opens into the mouth, where you can see the orifice projecting, like a little pimple, opposite the grinding teeth. Now, in wounds of the cheek, this duct is sometimes divided; and then the saliva cannot find its way into the mouth, but flows out upon the cheek, keeping the wound from healing. The part of the duct that has been cut off then becomes closed, and an operation is rendered necessary to restore the saliva to the mouth. For this purpose a passage is made by the knife, from the bottom of the wound directly through the cheek. A leaden ball or button threaded with many strands of silk is next procured, and the silk being passed through the cut into the mouth, the button is drawn into the

wound, close to the divided end of the duct. It is then easy to cause the skin to heal over the lead, while the saliva flows along the silk. After the healing, the button is removed by cutting upon it from within the mouth, and the constant flow of the secretion keeps open the new canal. In a few weeks, this new passage is found to be converted into a part of the duct, and is provided with regular integuments.

376. But the most remarkable proof of the similarity of structure observable in the internal and external integuments is the ease with which the mucous membrane changes into skin when kept dry by evaporation and exposed to light and air, and the equal readiness with which the skin becomes converted into mucous membrane when deprived of light and air and kept in a moist condition. Instances of the former kind you would not comprehend without more anatomical knowledge than is intended to be conveyed in this volume; but cases of the latter class are sufficiently familiar.

377. In young children and elderly people who are remarkably fat, the skin of the neck is frequently thrown into folds, so that a part is doubled inward until the light and air cannot freely reach it, while it is kept constantly moist by the condensation of the insensible perspiration (209), which cannot escape in the form of vapour. In such situations, the cuticle first swells, as it does on the hands of a washerwoman, and at length falls off in places, leaving the mucous surface of the skin exposed, and the papillæ in a great degree unprotected. The slightest accidents are then productive of great pain. If an attempt be made by the rete mucosum to secrete a new cuticle, it takes the form of a mere epithelium, and soon falls off again unless the part is occasionally exposed to the air. The terribly painful sores sometimes occurring between the toes, even in careful persons, are produced in precisely the same way. All such cases are readily cured, if taken in time, by frequent washing to remove the moisture of perspiration, and then exposing the part freely to the air, or dusting it again and

again with some mild dry powder. The new mucous membrane is then reconverted into skin.

378. Even here in the history of man, you see the simplicity of nature vindicated; for these remarks must have reminded you of the fact, that, in the hydra and polypi, the inner and outer surfaces are mutually convertible into each other.

379. You now perceive, most clearly, that the whole frame of man, with all its delicate machinery, is completely enclosed in an unbroken cover of integuments, through which every thing that enters the body, as well as every thing that leaves it, must necessarily pass. The whole frame may be compared to a cylindrical tube, and its surface, physiologically speaking, is not confined to the outside of the person. On the contrary, it is many times more extensive than the whole exterior. It includes the entire length of the alimentary canal, which, as you will hereafter learn, is at least thirty-six feet in length in a man measuring six feet in height. It includes the whole extent of the air passages, the larynx, the trachea, the bronchia, and the air cells of the lungs. It embraces the cavities of the mouth and nose, with the front of the eye and the tear-duct; and it even extends into several cavities within the solid walls of the bones of the upper jaw and several of those of the cranium, as will be explained in the next chapter.

380. Throughout by far the greater part of this vast surface, the delicate integuments are unprotected by a cuticle; yet they are every where liable to be acted upon injuriously by external agents. When you consider how severe is the pain produced by applying vinegar, brandy, or pepper to the surface of a blister after removing the epidermis; and when you reflect upon the follies into which we are continually led by the indulgence of appetite, you will fully comprehend the beneficence of Providence in supplying all the internal integuments with nerves of organic life, incapable of causing the sensation of pain, except when seriously diseased (305). Around the orifices of the mouth and nose, the sensibility of the nerves is very acute, and the thin epi-

thelium allows them to be acted upon by the slightest irritant, in order that we may be warned in time of the presence of any thing injurious in our food or in the air that we breathe; but the moment any powerful stimulus is fairly admitted into the alimentary canal, it ceases to produce pain, unless it acts as a poison and warns the mind of the danger through the medium of the sympathetic nerve (306).

381. At the orifice of the larynx, the sensibility of the integuments is so acute that even so mild an article as a drop of water cannot touch it without giving rise to a most violent cough and severe suffering; yet if, as sometimes happens, a pea or any other hard substance makes its way completely into the trachea, it is no longer felt until it produces disease. I once saw a young medical man in danger of destroying life from ignorance of this fact. A woman attempted suicide with laudanum. It was necessary to pump up the poison by means of a tube passed into the stomach. The surgeon passed the tube backwards to the throat, and instantly there was a violent effort to cough, and apparent suffocation. He did not pause, but hurried the tube downward, and the cough and spasm immediately ceased. He was on the point of forcing through the tube a quart of water, when I arrested his hand. The tube was in the lungs and not the stomach, but the instrument had passed the irritable part of the orifice of the larynx, and the patient breathed by the side of the tube. It was withdrawn and introduced again into the œsophagus, and the woman was saved.

382. When persons are drowned, or suffocated in certain poisonous gases, the water or foul air so acts upon the orifice of the air passage, that it is closed by a violent spasm, and not a drop of the water or a particle of the gas finds its way into the lungs until long after death. Were it not for this provision of Providence, such persons would never be recovered from the state of suspended animation.

383. It has been stated in the earlier part of this volume, that a considerable quantity of water escapes

from the lungs in the form of vapour during the act of expiration. This compensates in part for any deficiency in the power of the skin to purify the blood of its surplus water and certain salts (for perspiration always contains a portion of salts), by means of the ordinary secretions of the integuments. It was also stated that the skin of man was capable of contributing to the process of respiration, as does the back of the frog and the whole surface of many animals of less perfect organization. Now if our habits should prevent the free exercise of these functions of the skin, the lungs would be compelled to exert themselves so much the more industriously, in order to make up for the deficiency. They must respire more laboriously, and must discharge a larger portion of watery vapour with the breath. Such causes unavoidably produce debility from over exertion of the lungs in matters beyond the proper limits of their functions, and assist in bringing on consumption or other diseases of the chest. Care with regard to frequent ablutions, and the removal of the superabundant cuticle by means of the coarse towel or flesh-brush, therefore, promote essentially the healthfulness of the lungs. It has been found, practically, that the long continued and daily use of India-rubber cloth garments, covering a large portion of the person, checks in great degree the insensible perspiration and the respiration of the skin, and produces fatal consequences in the manner just described. The freedom with which the air and moisture find their way through flannel has, probably, much to do with its healthfulness as an article of dress. But I am not now writing on Hygiene, (the art of preserving health,) and these illustrations are introduced merely to show you the practical utility of facts and principles that may seem dull and uninteresting when not thus forcibly impressed.

CHAPTER X.

OF THE SKELETON AND ITS APPENDAGES.

384. THE several different classes of organs connected with the osseous system—the bones, the articular cartilages, and the ligaments—have been specified, and their general nature defined in a former chapter, (chapter v.); and it would be advisable for you to revise what is there stated, in order more fully to comprehend the following remarks.

385. The skeleton of an infant is, apparently, composed of many more pieces than that of an adult, because when the earthy matter or carbonate of lime begins to be deposited in the gristle, of which the entire bones are formed during the second stage of their growth (159), this new secretion commences in several parts of the same bone at about the same time. The intermediate space continues to resemble cartilage until the earthy materials of the different portions undergoing the process of complete ossification (160) are so far increased in quantity that this space is obliterated. Let us take the bone of the arm as an example. The two extremities of this bone, which contribute to the formation of the elbow and shoulder joint, ossify separately from the shaft; from which they are widely detached for a considerable time by gristle. It is not until the individual approaches mature age that all the bones are rendered perfect. This provision of nature is all-important to our safety during childhood; for it increases the flexibility of the bones, and deadens the effect of the innumerable falls and other accidents of early life.

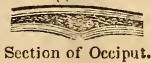
386. But, even in the adult, the skeleton consists of a multitude of pieces. Without counting the teeth, the

curious bone that supports the root of the tongue, and several smaller ones about the joints of the fingers, which, like the knee-pan or cap of the knee, are connected with tendons and act like pulleys, we may state the whole number at one hundred and ninety-seven. They are all constructed upon a uniform plan, being composed of cellular tissue filled with the cartilaginous and earthy deposits already described, and a peculiar fatty or oily substance, called the marrow or medullary matter:* but from the wide differences observed in their general form or outline, they have been divided into the long bones and the flat bones, though there are many which cannot be ranged correctly under either head.

387. The surface of nearly all the bones is apparently solid, and approaches, more or less, nearly to the appearance of ivory. In some places, this plate, or layer, is nearly half an inch in thickness; as in the middle of the thigh-bone; while in others it is thinner than a wafer, and is perforated by many holes of considerable size; as on the exterior of the bodies of the spinal bones. Internally, on the contrary, the osseous or earthy matter is arranged in the form of a network, or large cells, containing marrow.

388. The bones forming the cranium (321) are, for the most part, of the flat order (386), varying from one-eighth to half an inch in thickness. Their solid and dense sides are called the *inner and outer tables* of the skull, and the space included between them is called the *diploë*. It is filled with a multitude of small bony cells, freely communicating with each other, and forming a spongy-looking mass. Fig. 40 will give you an idea of this arrangement. It represents a small portion of one of the flat bones of the skull sawed through in the direction of its thickness. The inner table, which is thicker than the outer one at the particular part repre-

Fig. 40.



Section of Occiput.

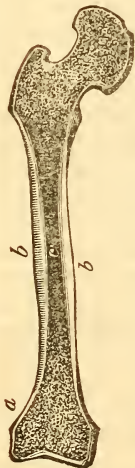
* This medullary matter has nothing in common with the medullary matter forming the chief part of the brain and nervous system; see paragraph 283; and this identity of name between such dissimilar substances, is peculiarly unfortunate.

sented in the figure, is usually thinner, and always much harder, bearing a tolerably close resemblance to ivory.

389. In the long bones, the solid walls of the middle portions of the shafts, where these bones are most slender, are very thick and strong; but towards the extremities, which are enlarged, to form powerful joints, the walls are thin and delicate.

390. On the contrary, the interior of the extremities is completely filled with small, spongy cells, like the diploë (388). These cells enlarge in size, and their walls become less and less perfect as you approach the shaft, until they form a mere loose network of bony fibres. Long before you reach the middle of the larger long bones, you find this network gradually disappearing from the central line of the cylinder, spreading itself in a thin and irregular layer over the thicker surface of the solid walls of the bone, and leaving a large cavity or canal within it, called the *medullary cavity*.

Fig. 41.



Section of the
Femur.

At fig. 41 you see a longitudinal section of the thigh bone, in which this arrangement is clearly shown: *a* represents the delicate solid table of the extremity next the knee joint, filled with its spongy cells of bone; *b, b*, shows you the thick, solid walls of the middle of the shaft; and *c*, the medullary cavity. The principal use of the solid walls and canal, in the middle of the long bones is, to lessen their weight without diminishing their strength, where grace and ease demand that they should not be very thick. The security of the joints while undergoing violent exertion requires that the bones that form them should have a broad and large surface of contact. If the bones had been made solid in these situations, they would have been too heavy for active motion. Had they been furnished, like the shaft, with solid walls, and a medullary cavity, the latter must have been made very large to effect economy in weight, while

the former would have been too brittle, and not sufficiently supported from within to withstand the severe shocks and strain to which the joints are continually liable. For these reasons, the extremities are formed chiefly of cellular bony matter, which yields a little, and thus destroys the effect of forces under which the more solid shaft would break if directly subjected to them.

391. Several different names are applied by anatomists to the loose bony matter, resembling the diploë, which occupies the interior of the bones; and as you may frequently meet with them in your reading, it is well to mention them here, although most of them are, in some degree, objectionable or partial in their application. It is termed *the cancelli* or cells, *the cancellated structure* or cellular structure, and the *reticular structure* or network of bone.

392. You have been told that the cellular tissue forms the foundation, or, to speak more accurately, that it is the *instrument* of the nutrition of all the organs of the body. It can never be wanting, then, in any portion of the bones. In the very earliest stage of their growth they are entirely composed of this tissue; and the only reason why it is difficult to demonstrate its existence in the most solid parts of the skeleton, is, that the cells of the tissue are there so completely filled with the gristle and phosphate of lime thrown out in the process of ossification, that a membrane so delicate and transparent cannot be perceived in the mass.

393. In the cancellated structure and the medullary cavity, the cellular tissue becomes much more obvious. It lines the cancelli, and fills up the entire medullary canal; being every where endowed with peculiar powers of life, enabling it to secrete the marrow, which fills these parts as it does the diploë in the flat bones of the head (388).

394. Even the most solid portions of the bones contain innumerable canals and cells, which only escape attention by their minuteness. Many of them are sufficiently visible where they have been divided by the saw, and others may be seen by the aid of the microscope.

In the short and flat bones, and the extremities of the long bones, these canals pass in all directions through the walls into the reticulated structure; but in the shafts of the long bones they pursue a very oblique direction, traversing the walls for a great distance before they enter the interior. When the animal matter is chiefly destroyed by burning or exposure to the weather, the bones are apt to break or fall to pieces by scaling off at the surface, and this has given rise to the opinion that they are formed of separate tables, placed one over another; but this appearance is merely owing to the direction of the long canals running obliquely through the harder parts and rendering them weaker in certain places. These passages communicate freely with each other by means of numerous branches; so that, in fact, the solid walls are really composed of a network of bony matter, differing from that of the extremities and the diploë only in having the meshes too small to attract attention. All these passages are lined by cellular tissue and filled with marrow, as may be ascertained at once by laying the fresh bone of an animal in the sunshine, after stripping it of its periosteum. The oily matter of the marrow will then flow out and collect on the surface in little drops.

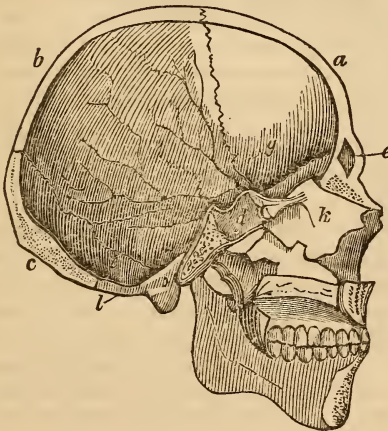
395. The minute vessels that supply the nourishment for the bones, and carry off the worn-out particles from them, are branches derived from the vessels of the periosteum (175). They enter the canals already described (394), and traverse even the most solid parts, supplying not only the gristle and earthy deposit, but the marrow also. They are much more numerous and larger where there is most of the diploë or cancellated structure in their interior. They are very small and comparatively few in number in the shafts of the long bones, but occur in such abundance near the extremities, that the walls of these parts are riddled by them like a sieve. But in those bones that are thick and bulky, and those that have a medullary cavity within them, we find one or more larger holes in the most solid part of the shaft or outer table, to give passage to as many larger

blood-vessels, the branches of which are distributed over the cellular tissue contained in the reticulated structure and the medullary canal. These large vessels are chiefly employed in the secretion of marrow; but when accidents, such as fractures, require them to assist in forming solid bone, they have the power to do so.

396. As the functions of the bones are entirely passive, they do not require the sense of feeling, and consequently their nerves are all received from the nervous system of organic life. They may be sawn or broken, when in health, without awakening any consciousness in the individual. There is a common opinion among the uninformed, that the marrow is exquisitely sensitive; but in truth it is altogether incapable of pain. Yet when inflamed, or otherwise diseased, the bones or the membranes secreting the marrow may be the seat of the most agonizing suffering.

397. After these remarks, you will be no longer surprised to hear that the bones themselves are sometimes affected by severe inflammation, abscess, ulceration and

Fig. 42.

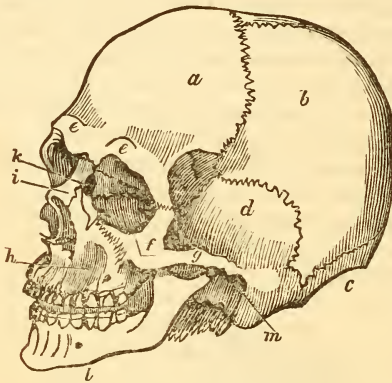


Longitudinal Section of the Skull.

other complaints, such as are seen in other parts. They are truly living organs, and share alike the benefits and the evils of life; and you have been informed already that they may change their character so completely in some cases as to be no longer bones (164).

398. It is now time to speak of the different portions of the skeleton, and the manner in which they contribute to the formation of the frame. And, first, let us consider the bony structure of the head.

Fig. 43.



Side view of the Skull.

399. The cranium, or that bony case which contains the brain, is composed of eight principal pieces, six of which belong to it exclusively, and two are so formed as to assist in constructing the frame-work of the face also. If you remove from the cranium all the bones of the face, there will remain a solid box inclosing a large cavity. In general form, it bears a strong resemblance to an egg, with the narrow end directed forward. The lower part of the egg is a little flattened and looks as though it had been crushed and indented in two places; first, on a line directly between the ears, and again, just behind the orbits of the eyes, where it is very

much flattened. Fig. 42 will give you a clear idea of the general form of the cavity and the relative thickness of the walls, which latter, however, varies much in different places, as you have been told (388). You observe that the upper part of the cavity is regularly and beautifully arched, but that its lower surface or floor is divided, by the indentations just mentioned, into three considerable depressions, designated by the letters *g, h, i*. As these depressions correspond exactly with three others on the opposite side of the middle line of the head, there are, in reality, six such depressions in the base or floor of the cranium. This should be particularly remembered, for you will find the fact important when we consider the structure of the brain, which fills this cavity entirely.

400. The anterior part of the egg-shaped box of bone is called the frontal bone. It forms the forehead, and in general shape somewhat resembles a clam or scallop shell, standing upon its apex or beak. You see it in its proper position, viewed in front, at *a*, fig. 46, laterally at *a*, figs. 42 and 43, and from above at *a*, fig. 45. It extends from temple to temple, and from the eyebrows to a distance of two or even three inches above the roots of the hair on the forehead. Throughout the greater part of this extent it is pretty nearly uniform in thickness, and possesses every where the two solid tables and the diploë very clearly marked (388).

401. But just within the eyebrows we generally find in the adult, two considerable cavities, one on each side (fig. 42, *e*), formed by a separation of the two tables, and an absence of the diploë at this spot. These cavities are called the *Frontal Sinuses*. They are usually separated from each other by a thin bony partition, which is often

Fig. 44.



The spinal Column.

incomplete, and sometimes wanting. The frontal sinuses are connected with the cavities of the nose by means of short canals or ducts passing through the solid wall of the bone, and they are lined with the mucous membrane which passes up from the nose through these ducts. The cavities thus communicate with the external air, and produce an effect upon the voice like that which would result from enlarging the barrel of an organ: the extent of the reverberation deepens the tone, and, in connexion with similar cavities in other bones of the head, they have much to do with the distinction between the bass voice of man, the tenor of woman, and the treble of childhood.

402. The frontal sinuses are not formed until mature age. They are often wanting and generally very small in woman. Even in man they are not always present. They differ very greatly in size in different individuals; being sometimes incapable of containing a drachm of fluid, and at others, though rarely, admitting many ounces. Though we can generally form some estimate of the size of the frontal sinuses by examining the edge of the orbit and the shape of the brow, this can never be accomplished with certainty; and we may be frequently deceived in attempting to judge the form of that part of the brain which lies over the nose and behind the eyebrows, by measuring the surface of the frontal bone. This difficulty has been much underrated by those cranioscopists who attempt to apply the principles of phrenology to the judgment of human character.*

* (To teachers.)—Phrenology is the science which treats of the functions of the brain. It is the highest and most difficult branch of physiology, and is altogether too recondite to form a proper subject for popular instruction. Something may be said hereafter of its objects and limits, but nothing of its details. It is proper, however, to mention here, that it is a purely *physical* science, and has no connexion whatever with *metaphysics*, though its founders and principal disciples have strangely confused these subjects in such a manner as to lead the incautious student toward fatalism and materialism. Believing, as the writer of this volume does, that Consciousness and Will, *the peculiar property of animals and the simplest elements of mind*, are not functions of the organization, or properties of any portion of the frame, this note seems neces-

403. The staggers—a disease not uncommon in the sheep and the deer—is occasioned by a worm hatched from the egg of a peculiar fly that lays its eggs in the nose of these animals. The worm, as soon as hatched, crawls up the duct (401), and makes its nest in the frontal sinus. There, the irritation produced by it occasions horrible pain, and being communicated to the membranes of the brain within, throws the animal into a state of frenzy, generally killing it in a short time. The same accident has happened occasionally to man. The worm might be easily destroyed by boring into the cavity, and filling it with oil. Even the ordinary inflammations of these sinuses are dreadfully painful, and sometimes very dangerous.

404. The frontal bone furnishes coverings for the orbits of the eyes. These consist of two very thin plates of bone, slightly arched, one of them extending directly backward from within each of the eyebrows. These are called the *orbital plates*, and in them we find the two tables of the skull pressed together, so that there is no diploë in this place. The plates are therefore very brittle as well as thin, and hence a thrust in the eye with a small sword is considered a fatal wound; for the point passes readily through the orbital plate into the brain.

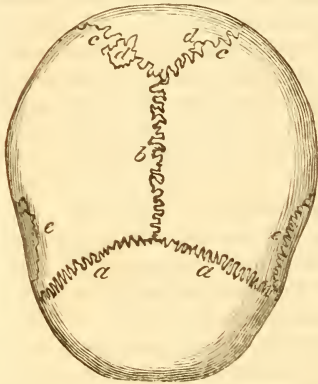
405. By the phrenologist, the frontal bone is believed to cover the surface of those organs of the brain which are the instruments of the reasoning and perceptive (or knowing) faculties of the mind. It is indented, internally, and particularly on the orbital plate, by numerous convolutions of the brain—parts that will be more particularly mentioned hereafter.

sary to save him from the charge of ignorance, where peculiar, though, he thinks, well-founded views that cannot be discussed in an elementary volume, have drawn him into positions at variance with those of the founders of an important but still nascent science.

Cranioscopy is the art of measuring the head in order to determine the form of different parts of the brain; and its perfection or defects do not necessarily involve the truth or falsity of the principles of phrenology. They merely affect the application of those principles to the practical judgment of character.

406. Two large bones connected together along the middle line of the head (fig. 45, *b*), form the upper part and sides of the great arch of the skull. They are called the *parietal bones*. They are seen at fig. 42, *b*, fig. 43, *b*, and fig. 45, *b*. Except that they are arched in

Fig. 45.



Top view of the Skull.

all directions, the general form of these bones is nearly square. They are thick, and present the regular appearance of two tables and a diploë more perfectly than any other bones of the head. At their lower edges they are bevelled off sharply where the upper part of the temporal bones (to be presently described) overlap them. The edges are arched upward, and the lower and anterior corner stretches downward towards the angle of the eye for a short distance. Internally, their surface is strongly grooved by the trunk and branches of the two great arteries of the internal periosteum or *dura mater*, which will be described hereafter, and are indented, like the frontal bone, by the convolutions of the brain.

407. The parietal bones cover the surface of those portions of the brain which are considered by the phrenologists as the instruments of the more purely moral sentiments of the mind.

408. The *occipital bone* forms the posterior part and a considerable portion of the floor of the cranium. You see it represented at *c*, fig. 42, *c*, fig. 43, and *d*, fig. 45. Its general shape is not unlike a clam-shell without a hinge, with its narrow beak lengthened out for at least an inch, and rendered very thick and spongy. This latter portion of the bone forms the middle portion of the floor of the cavity of the cranium: it is almost exclusively of a cellular or reticulated structure, having

but very thin and imperfect solid walls (389). The rest of the bone is constructed on the same plan with the bones already described. Its outline, if we except the beak,—or, as it is termed by anatomists, *the cuneiform or wedge-shaped process*,—is like a bent lozenge, with one of its corners directed upward (*d*, fig. 45), and the other downward, or rather forward, underneath the skull.

409. Near its lower angle, upon which the cuneiform process is grafted, we observe a large hole called the *great foramen*, (fig. 42, *l*), through which passes the spinal marrow, on its way to the canal of the spine, which will be described hereafter.

410. The inner surface of the bone is divided into four compartments by a strong, thick, bony cross, glued, as it were, upon the inner table. The upright limb of this cross runs from the great foramen to the upper angle of the bone (*d*, fig. 45), which angle corresponds with the crown of the head, where the hair divides. The horizontal limb of the cross winds round to the lateral corners of the lozenge; and their place of meeting corresponds exactly with that solid lump of bone which is felt on the most prominent part of the back of the head.

411. This cross gives great strength to the bone, particularly in the centre, where its limbs meet. This is by great difference the thickest and strongest part of the arch of the skull, and is provided with a great quantity of the diploë, as is seen in fig. 40, which is a transverse section of the part, and at *c*, fig. 42, which presents you with a longitudinal section. The structure of this part, and that of the frontal bone at the eyebrows, most beautifully display the wisdom of the Creator in the minute details of our organization. These prominent portions of the skull are most subject to blows and to injury in falls; and were it not for the frontal sinuses separating the two solid tables or the great abundance of spongy diploë at the centre of the occiput, which deaden the effect of concussions, few of us would reach mature age without suffering from injury to the brain within from unavoidable accidents.

Fig. 46.

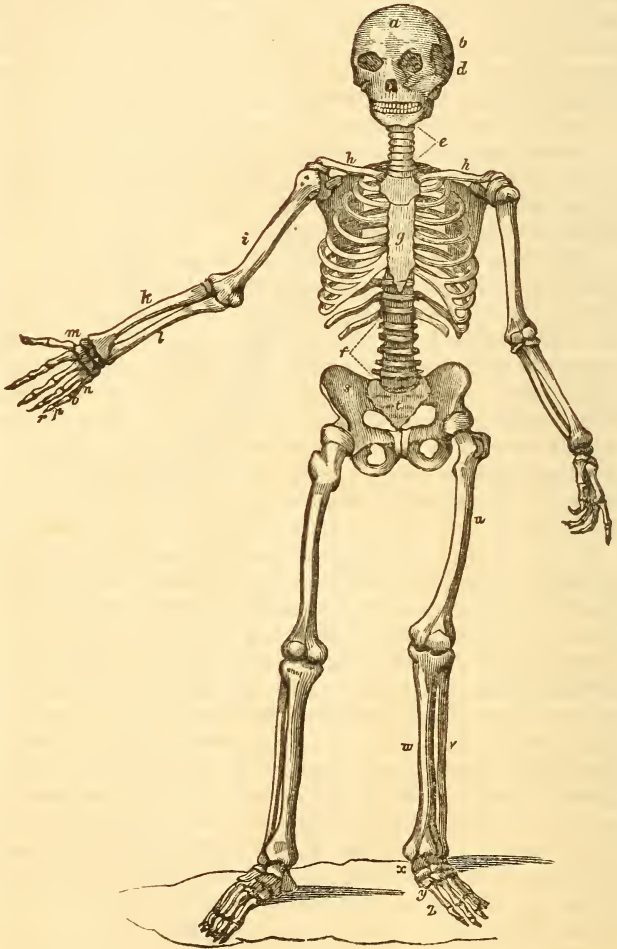
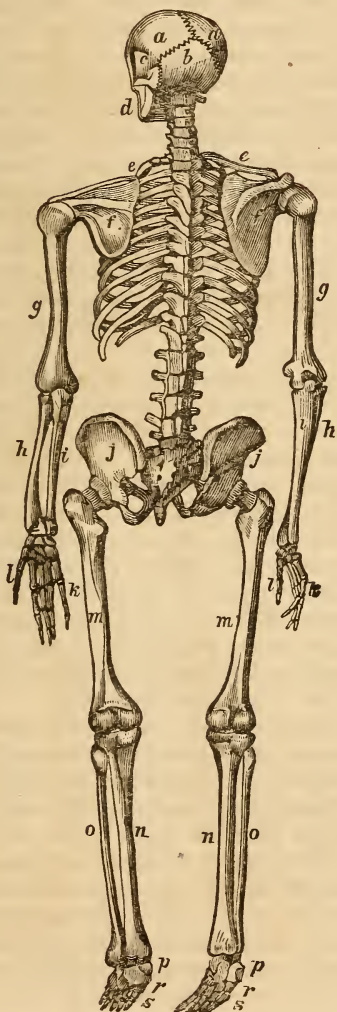


Fig. 47.



412. The limbs of the cross divide the occipital bone into four compartments, each of which is somewhat excavated, so that they form four depressions. The two lowermost of these correspond with the posterior depressions of the base or floor of the skull already mentioned (399). They contain a portion of the brain regarded by phrenologists as purely instinctive in its functions. This is so different in appearance, and so nearly separated from the remainder of the brain by intervening membranes, that it is called the lesser brain or *cerebellum*, to distinguish it from the greater brain or *cerebrum*. The two superior depressions situated above the horizontal limb of the cross receive the posterior part of the cerebrum, which is supposed to form the instruments of the mind in what relates to the social affections.

413. The greater part of the sides of the cranium above and around the ears are formed by two bones called the temporal bones. They are composed each of two portions very different in structure. The first portion, called the *squamous or scaly plate*, seen at *d*, fig. 43, and *e*, fig. 45, is part of the arch of the cranium. It has the two regular tables of the other bones, but is hard and brittle, containing very little diploë. The upper edge of this plate is nearly semi-circular, and is bevelled away from the inner side until it becomes quite sharp, giving it a scaly appearance. This bevelled edge overlaps the margins of the surrounding bones to a considerable distance.

414. The second portion of the temporal bone is called the *petrous or stony portion*. It forms part of the floor of the cranium. In shape it resembles an irregular triangular prism, lying upon one side, with the opposite angular ridge directed upward towards the brain. This portion, as its name implies, is formed of very solid bone, though many very important canals and cavities exist within it, among which may be mentioned all the cavities for the accommodation of the organ of hearing, the canal for the passage of the principal artery of the brain, the passage for the tube conveying

air from the throat to the drum of the ear, the closure of which causes incurable deafness, and the canal through which the nerve commanding the motion of the muscles of the face pursues its course.

415. The petrous portions of the temporal bones run obliquely forward and inward, nearly to the middle of the floor of the skull. Their angular ridges seem like a continuation of the horizontal limb of the internal cross of the occipital bone, and with it, form nearly a circle around the posterior depressions of the floor of the cranium, marking the dividing line between the cerebellum and the cerebrum (412).

416. Just behind the ear you feel a large and prominent piece of bone pointing downward. This is the posterior angle of the temporal bone. It contains a number of large cells communicating with the drum of the ear, and of course admitting the air. If the tube running from the drum of the ear to the throat were closed (414), we might restore the lost hearing for a time by boring into these cells. This has been done in a few cases, but surgeons have not yet been able to keep the wound open for any great length of time.

417. A long and narrow bridge of bone springs from the temporal bone just before the ear, and unites, at its extremity, with the bone of the cheek. A principal muscle closing the lower jaw arises from the temple, and passes under this bridge. Just within the base of this bridge is found the cavity of the joint of the lower jaw.

418. Of the two remaining bones of the cranium, which assist also in supporting the face, the largest is called the *sphenoid bone*. In form it is compared to a bat, with its body, legs, and wings, but it is unnecessary to attempt a particular description of it. The body forms the centre of the floor of the skull. It is hollow, containing one or two very large cells (fig. 42, *d*), with thin and delicate walls. These cells communicate with the throat, and produce an influence on the pitch of the voice (401). This bone stretches entirely across the

skull; forms a great part of the floor of the middle depressions of the base of the cranium, and also the posterior edges of the anterior depressions (399). It also furnishes a broad plate to each temple, which lies between the edges of the temporal bone behind, and the frontal bone before.

419. The only bone remaining to be noticed is called the *ethmoid bone*. It is chiefly concerned in constructing the upper part of the outer sides of the nostrils, where it forms a number of cells with their partitions, over which the branches of the nerve of smell are distributed. Two considerable portions, which are situated on opposite sides of the nose, are joined together by a very thin horizontal plate called the *cribriform plate*, forming a roof for the nose, and separating that cavity from the brain. This plate is completely riddled by minute holes that give passage to the branches of the nerve of smell, as they leave the cavity of the cranium. It is very small, and lies between the orbital plates of the frontal bone (404), before the front edge of the sphenoid bone, and immediately behind the root of the nose. A severe blow on the last named spot may crush this cribriform plate, which is not much thicker than paper, and the consequence is generally fatal.

420. The flat bones of the skull are connected together at their edges by tooth-like projections which interlock with each other, forming a zigzag line called a *suture*; so that the arch formed by them is nearly as solid as if constructed of a single piece, and the bones cannot be detached without breaking some of the teeth. In fig. 45 you see several of the principal sutures: *a, a*, represents that which separates the frontal from the parietal bones; *b*, that dividing the parietal bones from each other; *c, c*, that which lies between the occipital and the parietal bones; and *e*, the suture between the temporal and parietal bones.

421. The cranium, thus constructed, is covered by the periosteum externally, and by the dura mater within. Between these membranes the cartilaginous and earthy matter of the bone are secreted together, and not, as

in other parts of the skeleton, successively. But during childhood the bones of the skull remain, for a time, comparatively soft and flexible; so that they may be bent or indented without breaking. Certain savages have a custom of binding flat boards upon the heads of children, in order to prevent the skull from growing in particular directions. The bones, by their softness and flexibility, yield gradually to this pressure; and when, in after life, they become firm and brittle, the head appears permanently deformed. The different portions of the brain readily accommodate themselves to such changes in early life; and the functions of those all-important organs are not materially affected by these superstitious habits. Some erroneously suppose that these alterations in the form of the skull are believed by phrenologists to modify very seriously the powers of the mind, and a notion of this kind is excusable even in a teacher of the science, if he be not well grounded in the principles of physiology. The changes alluded to only serve to render it much more difficult to judge of the form of different parts of the brain from that of the outside of the cranium; and as they are sometimes produced by accident as well as by art, he should be a thorough physiologist who undertakes to decide such questions with even tolerable certainty.

422. When, in infancy, the bones begin to ossify, most of those of the cranium are formed of many pieces. Thus, the two sides of the frontal bone are separate from each other, and the edges do not come in contact. Now and then it happens that the ossification goes on too slowly in the principal portions, and nature, seemingly in haste, sets about secreting bone in one or more places in the intervals. Each of these spots being the centre of a separate ossification, there result as many little accessory *accidental bones*, if you will allow me such an expression. When completed, these bones are attached to the larger ones by sutures, as these latter are to each other. Two such accessory bones are seen at *d, d*, fig. 45, between the occipital and parietal bones.

423. In very young children, the bones of the skull

are very incomplete; their edges being widely distant, especially at the corners, where the head is soft to the touch; and you can plainly see or feel the pulsations of the brain within. At these places which correspond with the position of the sutures, the brain is enclosed simply by the periosteum and dura mater, with a little loose cellular membrane between them, designed to receive the bony deposits as the child advances in age.

424. To the arrangements just described (421, 422, 423), we are often repeatedly indebted for our continued existence before we complete the first year of life. Were it not that the skull can yield, and the edges of the bone approach or separate from each other by stretching or pressure, every little jar from a fall or a blow would be felt in full force by the soft and delicate brain; and in many cases of unavoidable accident, this part would be torn. As it is, even a fracture of the skull is much less important to a young child than to a grown man; and the former will often survive a fall that would be fatal to the latter. In fractures with depression of the skull, in childhood, if the pulsation of the brain should not elevate the pieces to their proper level, the rest of the head is immediately enlarged to accommodate the brain; but, in youth or manhood, the patient dies by the pressure, or lives to be subject to convulsions from the continual irritation of the brain.

425. When dropsy of the brain occurs in very early life, the cranium may become enlarged till it nearly equals the chest in its dimensions; yet the child may sometimes live to maturity, though generally in a state of idiocy. But when the same complaint happens in persons over five years of age, it is speedily fatal; because the bones cannot increase in size rapidly enough to prevent fatal pressure on the brain.

426. It is now well ascertained that the cultivation of the mind slowly enlarges and changes the shape of the cranium, even after maturity; and it is equally well known that the bones of the head generally contract upon the brain as it becomes emaciated by age, though, in some few rare cases, they are increased in thick-

ness instead of being diminished in size. You cannot be surprised at this fact, when you know that all the bones will grow when the muscles attached to them are much and properly exercised, and that they dwindle away, like the muscles, when unemployed. These things are but so many evidences of the truth of the law that, the more the function of any organ is exerted, unless it becomes exhausted, the more active will be its nutrition. Let this be a stimulus to you in the endeavour continually to strengthen, by exercise, all those useful powers of body and mind in which you find yourself deficient. All such endeavours are like investments at compound interest;—the income is continually added to the capital.

427. The form of the cranium, arched in all directions, except on its under surface, where it is protected from injury by the neck, gives it all the strength of a bridge. But you know that when a great weight is placed on the centre of a bridge, it is more likely to give way at the extremities than at the spot where the weight presses; thus a heavy blow or fall on the head often breaks the skull, not on the part which directly receives the injury, but at the sides of the head, where we should find the abutment of the bridge. But this arrangement is a proof of the beautiful economy of nature, for it is that which gives the greatest degree of strength with the least amount of material. A sharp, quick blow, with a small, heavy instrument, such as a hammer, or steel cane, will generally break the skull at the spot which receives it; as a cannon ball, or a fragment of a blasted rock, will pass through the plank of the bridge without shaking the abutment.

428. The cranium, constructed as has been described, sits upon the summit of the column of the spine, fig. 44, page 185, with the two uppermost bones of which it is articulated in a very curious manner. On each side of the great occipital foramen, *l*, fig. 42, there is a projection of spongy bone, covered with cartilage, forming a joint, with a corresponding depression at the side of the first spinal bone. This joint permits the head to be

raised, to rock, or to bow forward till the chin nearly touches the breast. But if the same joint had been so constructed as to allow the head to turn upon it freely from side to side, it would have been too liable to dislocation, an exceedingly dangerous accident that has sometimes happened when the head has been very suddenly and violently turned round. The dislocation can only happen upon one side at a time; and when it occurs, the face is turned towards the corresponding shoulder. To restore it to its natural position again, is an operation that few surgeons would have the hardihood to attempt; for the slightest unsteadiness of hand might be instantly fatal to the patient, by compressing the spinal marrow as it descends through the foramen. In order, then to allow the head its proper freedom of circular motion, another arrangement is necessary.

429. The uppermost bone of the spine is little more than a bony ring, with cavities on its upper surface to receive the projections by the side of the occipital foramen mentioned in the last paragraph, and with two similar projections on its under surface, designed to form a joint with the second bone of the spine.

430. To prevent repetition it may be well to inform you that such prominences of bone as are designed to assist in forming the movable joints are called *condyles*.

431. The second spinal bone of the neck is not a simple ring, but is constructed like the other pieces of the spinal column, fig. 44, with a large mass of spongy cellular bone in front, called its *body*, supporting an arch or bridge of bone on its posterior side, to surround and protect the spinal marrow. A long round piece of bone projects upward from the body, passing through the ring of the first spinal bone, and rising to the level of the occipital foramen. This piece is covered with cartilage both in front and rear. In shape it resembles a round tooth, and this circumstance gives it the name of *vertebra dentata* or toothed vertebra, while the uppermost bone is fancifully styled the *atlas*, from its dignified office in giving immediate support to the head.

432. The tooth-like process of the *vertebra dentata* is

held firmly against the anterior part of the ring of the atlas by a very strong ligament stretched across the ring behind it, and it is securely attached to the atlas and the occipital bone by several curious ligaments which keep it in place, while they permit the head to bow and rock to a certain extent, and to perform its other necessary motions.

433. When the head turns from side to side, the atlas travels with it, and the condyles by which it is articulated with the vertebra dentata are so constructed as to permit this motion to be carried to a certain distance with safety.

434. But none of the motions of the head can be carried very far forward, backward, or to either side, without the aid of all the spinal bones of the neck; and on great occasions, the whole body must be called into action. Were more motion allowed to the immediate articulation of the head with the spine, the spinal marrow would be in constant danger of being crushed by the pressure of the tooth-like process of the second vertebra; which is the cause of death in the fatal attempts to replace a head that has been dislocated.

435. The muscles which support the head and give it motion are very numerous; and as the head always has a tendency to fall forward by its weight, those which draw it backward are larger, stronger, and acquire more tone from habitual exercise.

436. The muscles of the head originate from the spine, the shoulder-blade, the collar-bone, the breast-bone, and the ribs. All the motions and peculiar conditions of these various parts must influence the attitude of the head. For example; an inflammation of the spinal periosteum or rheumatism of the shoulders, compels a patient to stoop, because the tone of the muscles that raise the head is diminished by this disease, and their action rendered painful. A palsy of one side causes the head to be carried toward the opposite shoulder, for the same reason. Changes of the whole figure and serious injury to health often result from the long continued operation of these seemingly trivial causes.

But this subject will be more properly discussed in a future chapter.

437. As we are studying physiology and not anatomy, we may now relinquish the details of the structure of the cranium, and it will not be necessary to dwell long on that of the face, as it illustrates no very important principle necessary to my scheme.

438. The bony structure of the face is very complex; being composed of fourteen bones, exclusive of the teeth, which are thirty-two in number. You would learn more of these bones in one hour from an examination of the real skull in the hands of a well instructed physician, than in the study of description, even with the aid of the best plates, for a month; and I shall confine myself to a few remarks upon the jaws and teeth.

439. The upper jaw is composed of two bones, united in the middle, fig. 43, *h*. They form two-thirds of the floor of the nose, the roof of the mouth, or the bony palate, a part of the side of the nose, and a considerable share of the floor of the orbit of the eye. They also afford the chief support to the other bones of the face; yet they each contain a very large cavity communicating with the nose, lined—like those already noticed in certain bones of the cranium—with mucous membrane, and constituting a portion of the surface of the body. The walls of this cavity are very thin in many places; so that were it not that we habitually and instinctively shield the face from danger, they would be very liable to fracture from accidental violence; but injuries of this kind are exceedingly rare.

440. Several important nerves of sensation pass through small canals in the walls of the upper jaw, as others, already mentioned, penetrate the solid portions of the temporal bones (414). When the periosteum lining one of these canals becomes inflamed, there is not room enough to accommodate the swelling thus produced, and the enlarged membrane, pressing forcibly upon the nerve, occasions intense pain. Many cases of that formidable disease called the tic douloureux occur

from this cause. Rheumatism is often an affection of the periosteum, and frequently gives rise to the complaint just mentioned. All the nerves which pass to the teeth, whether in the upper or lower jaw, are inclosed in canals of solid bone; and in cases of cold, or disease of a tooth, inflammation may be extended to the periosteum of these passages. All the teeth in either jaw may be thus affected with toothach, and the sufferer or the dentist may be unable to discover exactly where the evil commences.

441. There are sympathetic connexions between the nerves of the teeth and many of those of the ear, the muscles of the face, or even the eye. From this circumstance, injuries or decay of the teeth give rise, in some rare cases, to blindness, deafness, or palsy of the cheek. It is impossible to explain these connexions except to profound anatomists; but you may judge of their importance when I tell you that I have seen the whole cheek and the lower eyelid palsied, so that the mouth was distorted, the eye could not be closed, and the hearing was much impaired, by a slight and unavoidable accident in the extraction of a tooth. Fortunately, the alarming consequences resulting from this cause are not very lasting: I have never known any of them to continue beyond a few weeks. When they are occasioned by decay, by rheumatism, or by diseases of the jaw, they may endure as long as the cause on which they depend. Extraction of a few carious teeth has been known to cure a deafness of long standing, or to improve defective vision.

442. The teeth are not constructed upon the same principle with the other bones: each of them seems to be an osseous incrustation upon the surface of a nervous papilla (350). In some animals they grow for a long time after they are in use, like a hair (356), by deposition of new layers upon the root. This is the case with the tusks of the elephant, the boar, &c.; but they differ from hair and other appendages of the cuticle in possessing vitality and sensation in their very substance. This has been denied by most writers; but every dentist

knows that the diseased bone in a carious tooth is sometimes exquisitely sensitive under the action of an instrument that does not approach the nerve. Moreover, I have been convinced by experiment, that in health a tooth perceives, obscurely, what part of its surface is touched by any foreign body. Blood-vessels and nervous matter exist in abundance within the cavity and "pulp" of every tooth; but have not been traced into the solid portions.

443. In man the teeth are all constructed within little membranous sacs, bedded in portions of soft spongy bone forming the margins of the jaws, and called the *alveolar* or *socket processes*. When the body of a tooth has reached its full dimensions, the membranous sac containing it secretes, over its upper surface and around its sides, what is called the enamel. This, though resembling in its chemical structure the earthy matter of bone, contains very little, if any, animal matter. It crystallizes upon the bone beneath it, and becomes so hard that it is difficult to act upon it by tools of the hardest steel. It is utterly devoid of life or sensation, though it transmits impressions to the bone and nerve beneath, as the cuticle does to the papillæ of the sense of touch.

444. When the body of the tooth has been constructed, the root begins to grow, in the form of one or more *fangs*, and contains within it a branch of the nerve with the necessary blood-vessels, like the bulb of a hair. The junction between the fangs and the body is called the neck. It is narrower than the neighbouring parts of the organ. The periosteum lining the socket doubles upon itself, and envelopes the fangs or roots as high as the neck, where it adheres closely; and the enamel descends from the crown of the tooth to the same spot. As the roots grow, the crown is thrust outward from the socket, the summit of the secreting sac is absorbed, the gums covering the part are removed by the same process, and the naked tooth appearing, soon rises to its proper height by a process somewhat resembling that which forms the hair and nails. The business of nutri-

tion then ceases in the tooth, and it stands unchanged until disease, accident, or the progress of age removes it:

445. When the teeth of man are worn down by use until there is danger of the cavity being opened, new bone is secreted within the part; and sometimes in old persons the cavity becomes completely filled in this manner; but the new bone thus formed, is often so tender to the touch that, when irritated, it becomes painful, and is mistaken for genuine toothach. The same mistake is often made when the periosteum is inflamed, though the teeth may be uninjured. Both these forms of disease may be generally cured by a treatment similar to that required in other local irritations. You perceive, then, that a good dentist should be also a well-informed medical man; and that his profession is one of more dignity than is commonly supposed.

446. We often hear an operator blamed for "breaking the jaw" in extracting a tooth. The form of the roots of many teeth is such that this accident cannot be avoided; but it is altogether unimportant; for the teeth are seated in the spongy alveolar process, and never penetrate the firm bone. When the socket is broken, and the piece removed, the patient is sometimes the gainer; for, after the removal of the organ, the socket is always absorbed; and its destruction is hastened by the fracture. It is this absorption of the alveolar process that occasions the approximation of the nose and chin in very old people; and, as it sometimes takes place before the teeth decay, their support may be thus undermined, and they may fall out in a sound condition. All this tends to prove the general law that the moment parts cease to be exercised sufficiently they begin to diminish in strength; and when they become unnecessary they are removed.

447. The shedding of the milk-teeth, or the set that first appears in infants, resembles in some respects the annual shedding of the horn in the deer and other animals. A new tooth is formed in a new sac beneath the old one, and the connexions of the latter are absorbed, until it is pushed off from the gum, or, until we extract

it to relieve nature and promote comfort, as the stag rubs off his useless honours at certain seasons by pushing them against a tree.

448. The language of the teeth teaches us the utter folly of the dreams of certain empirical enthusiasts who would persuade us that duty or health should confine mankind to one particular species of food, and it equally exposes the impropriety of many habits common in families, that prove destructive to the health of children.

449. The four front teeth in either jaw are called *incisors* or cutting teeth. They are constructed like those of all quadrupeds that graze or subsist upon fruits and vegetable matter exclusively. They are not sufficiently strong to tear the tougher meats, nor are their crowns broad and flat enough to grind the larger and harder roots and other vegetable food. They are the first to appear in childhood; thus most clearly showing that when the natural food of infancy becomes insufficient in itself to support the frame, *animal food was not designed immediately to supply its place*. When these teeth fall, they are replaced, in the growing youth, by others of the same kind, but much larger and stronger than their predecessors; proving to all who study the beautiful, simple, and consistent designs of Providence, that a vegetable diet, to a certain extent, is still necessary to the health of man.

450. Next in order, after some time, appear four temporary grinders—one on each side of each jaw—fitted for the mastication of little else than vegetable matter. At a still later period the canine or eye-teeth, sharp and conical and made for tearing, are added to the list. These resemble the teeth of the beasts of prey which subsist entirely on animal food, and whose jaws are armed with such instruments alone; being divested of proper incisors, and provided even with grinders of which the summits are studded with conical eminences that act with greater force but in much the same manner as the sharp-pointed front teeth. You may readily and safely examine these teeth in a tame cat or dog. After the canine teeth, four other temporary grinders, of the

same character with those mentioned above, make their appearance, and the set of infant teeth is perfected to the number of twenty.

451. The proper time pointed out by nature for permitting a child to partake of the ordinary meats of the table, is the period when the canine teeth have reached their perfect condition.

452. All the infantile teeth are lost in early life; but these are regularly replaced by others of similar character and greater size, while, by the addition of twelve more grinders, the number is raised, in manhood, to thirty-two.

453. Now the existence of the canine teeth through life furnishes evidence that an exclusively vegetable diet was not designed for man, and at once betrays all the absurdity of those strange doctrines which reduce the natives of India to feebleness of mind and body, and are now effecting the same lamentable consequences among certain enthusiasts in our own enlightened land. Even the form of the human grinders furnishes another proof of the same fact. Their crowns are provided with eminences of an intermediate character, between those of the grazing animals on the one hand and the beasts of prey on the other; being equally well fitted for crushing the esculent roots and the flesh of animals. So unerring is this language of the teeth throughout the whole range of quadrupeds, that if you were to present an experienced naturalist with the jaw of an unknown animal, he would at once inform you correctly of the nature of its food.

454. Were I treating of the art of preserving health, I might profitably enlarge upon this subject, but in a volume on the elements of physiology, I must leave the application of the principles mainly to yourselves.

455. There exists an evident sympathy between the stomach and the teeth; and any disorder of the one is dangerous to the health of the other. A want of cleanliness and daily attention to the former, or the injurious trifling of an unskilful dentist, is not only destructive of beauty, but increases the liability to dyspepsia with all

its train of suffering, gloomy feeling, misanthropy, and irritability of temper, rendering life miserable, even if it be not curtailed by the imperfection of mastication—the first and most important step preparatory to digestion. On the other hand, the constant indulgence in the eating of indigestible and doughy cakes during childhood, the iniquitous conduct of certain parents in encouraging the use of stimulating drinks at the same tender period, and the ridiculous, if not criminal habits of diet adopted in gay society, are very frequently destructive of the teeth. Need we be surprised then that dyspepsia and bad teeth are so increasingly common as to lead uncourteous travellers and men of the olden time to regard them as peculiarly characteristic of the American climate or the degeneracy of the times?

456. Although the mere mechanism of the head would furnish an ample subject for this entire volume, it is now time to glance over the remainder of the skeleton. In doing so, I shall avoid all unnecessary anatomical detail, but I must beg your undivided attention to the few remarks of this character which cannot be avoided.

457. *The spine*, which is the most important part of the frame-work of the trunk, extends from the lower part of the loins to the head, along the back of the body, where it may be plainly felt throughout its entire length. It is composed of twenty-four pieces of bone called *vertebræ*. It forms a column somewhat, but not quite regularly conical; and instead of being perpendicular, it has several curvatures, giving it somewhat the form of the letter S, inverted; as you see in fig. 44, page 185, which represents it detached and in profile. When you regard it in front or rear, it appears straight.

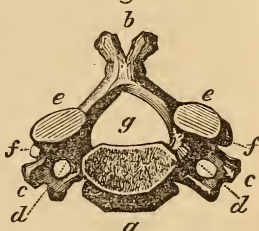
458. Of the twenty-four *vertebræ*, seven belong to the neck, and are called the *cervical vertebræ*,—twelve to the back, called the *dorsal vertebræ*,—and five to the loins, called the *lumbar vertebræ*. The cervical part of the spine curves gently forward, to bring it more nearly under the centre of gravity of the head, which it supports. The dorsal portion sweeps widely backward, to enlarge the cavity of the chest: and the lumbar portion again projects anteriorly, to restore the balance.

459. The conical form of the spinal column is principally owing to the shape of the bodies of the vertebræ (431), which constitute by far the largest portion of each of these bones, except the atlas, which has no body, (429, 431).

460. Fig. 48 represents one of the cervical vertebræ, and will serve us to explain their general form and their several parts. At *a*, you see the spongy body of the bone, with its upper surface slightly excavated, but nearly flat. The under surface is also flattened. From the sides of the body you see a bridge of bone encircling an open space, marked *g*.

This is a portion of the long canal running the whole length of the spine, completed partly by the bones and partly by the surrounding soft parts, for the accommodation of the spinal marrow. At the abutments of this bridge you perceive two smooth surfaces (*e, e*) seated upon jutting portions of the bone (*f, f*). These planes are coated with cartilage. They are the condyles (430) for the articulation of this vertebra with the next one above. On the lower part of the same portions of bone (*f, f*) are two corresponding surfaces, which are the condyles for the articulation with the next vertebra below. From the sides of the abutments of the bridge arises a bony prominence on either hand (*c, c*), with a hole or foramen (*d, d*) passing through it. These prominences are called the transverse processes, and are chiefly designed to give origin or attachment to the muscles of the back. The holes in them are peculiar to the cervical vertebra, being intended to give a secure passage to a considerable artery of the brain, called the vertebral artery, on its way to the cavity of the cranium. At *b*, you observe a portion of bone pro-

Fig. 48.



A Cervical Vertebra.

a. The body. *b.* The forked spinous process. *c. c.* Transverse processes. *d. d.* Holes for the cervical arteries—also grooves for the spinal nerves. *e. e.* Superior condyles. *f. f.* Process of bone supporting the superior and inferior condyles. *g.* Part of the spinal canal.

jecting from the middle of the bridge. Each vertebra is furnished with a similar process, and all these bones may be counted with the finger passed along the back, where they often occasion visible elevations. They are called the *spinous processes*, and, like those previously mentioned, they furnish origin and insertion to muscles of the back. The fork at the extremity of the processes is peculiar to the cervical vertebræ. Except in this last respect, and in the presence of the holes through the transverse processes, all the vertebræ, except the atlas, resemble each other; but the comparative bulk and direction of the different parts are very various in different parts of the spinal column.

461. The articulations of the condyles of the vertebræ are altogether insufficient to support the column securely without further aid; and to meet this difficulty, the bodies of these bones are joined together by intermediate rings of a peculiar substance, partaking of the nature both of ligament and cartilage. This elastic substance acts like a cushion between each pair of vertebræ; and while it allows the column to bend in all directions, as far as the bones will permit, it is softer, and almost semi-fluid, in the centre of the column, and becomes firm and more fibrous towards the circumference of the bodies of the bones. The middle of each of these cushions acts like a pivot, and the circumference, like a ligament, to prevent excessive motion. Though these rings of elastic matter are not exactly similar in their organization to the articular cartilages,—being more like the gristle of young bone mixed with fibres of periosteum,—they are known to many by the rather inaccurate title of *intervertebral cartilages*. The substance of which they are composed is called *fibro-cartilage*.

462. The spinal fibro-cartilages are gradually compressible to a certain extent, even by the weight of the body, and consequently, a tall man sometimes measures nearly an inch less in height in the evening than he does in the morning, a little diminution of distance between each pair of vertebræ taking place from pressure when the body is erect, and being regained by elasticity in the

reclining posture. The emaciation of these rings, from defective nutrition in old age, is one of the causes of the diminished stature of elderly people; but this is much increased by a similar change in the bodies of the vertebræ themselves.

463. The spinal column, with its bones thus connected by regular joints between the condyles, and by intervertebral fibro-cartilaginous rings, is strengthened by very numerous ligaments, passing not only from the body of one bone to that of another, but also between the edges of the transverse and spinous processes and the sides of the bridge of bone (460), both within and without the rings (fig. 48, *g*), formed by these parts. These rings, and the ligaments just mentioned, form one great canal for containing the spinal marrow, and the origins of most of the nerves of sensation and voluntary motion. It is called the *spinal canal*, and extends throughout the entire length of the column, from the great occipital foramen (409) to the last lumbar vertebra. This canal is, in fact, a continuation of the cavity of the cranium, being lined throughout by the same membrane that envelops the brain.

464. The number of bones forming the spine is of the utmost importance to the safety of life; for, if the spinal marrow be seriously injured, the parts receiving their nerves from below the seat of injury are instantly palsied, because the nervous communications with the brain are thus destroyed. The higher the point injured, the more important the organs rendered powerless; and if it be near the upper extremity of the column, speedy death must follow; for you can readily perceive that if the muscles of the chest are paralyzed the patient cannot breathe, and the nerves supplying these muscles spring from the upper part of the spinal marrow. Now it is absolutely necessary that the spine should bend in all directions to a considerable extent, and that it should even be capable of twisting upon itself in order to allow the person to assume the various requisite attitudes. If any of these extensive motions were performed at any one spot, the shape of the spinal canal would be so far

changed in that place that the spinal marrow would be inevitably and fatally crushed. But, by distributing these motions through a long series of joints, nature accomplishes the changes far more gracefully by a gentle curvature that does not materially alter the form of the canal or endanger its contents.

465. The cervical vertebræ require extensive mobility in all directions to accommodate the head; and the lumbar vertebræ have considerable powers, both of flexion and rotation. The dorsal vertebræ, on the contrary, have scarcely any motion, for their spinous processes point very obliquely downward, cover each other like the shingles of a roof, and even interlock themselves by means of a ridge on their upper surface and a groove on the under side. In order to furnish additional security to the spinal marrow, the spinal canal is made proportionately very large in the neck, *where the extent of motion is greatest*,—large in the loins, *where it is still considerable*,—and quite small in the dorsal region, *where it scarcely exists*. How beautiful is the mutual fitness of all parts of the complex frame!

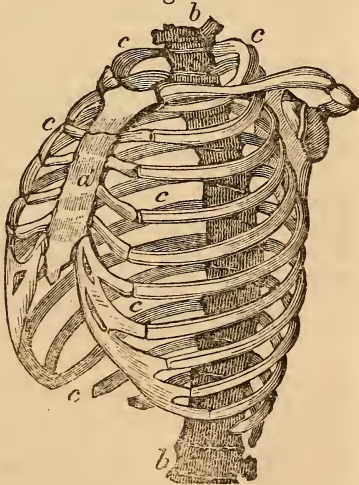
466. In those unfortunates who labour under decay of the bodies of the vertebræ, producing certain deformities of the spine, the spinal marrow is in great danger; and weakness, if not palsy of the lower extremities, results. When these cases recover, as they sometimes do, the ligaments, and occasionally the fibro-cartilages around the diseased vertebræ, are converted into bone, so that several pieces of the spinal column become one piece, and the proper motions of the part are for ever destroyed. The same thing may occur in old age.

467. The nerves which go off from the spinal marrow (292—Fig. 37), pass through small orifices in the ligamentous and membranous lining of the spinal canal, and are accommodated in their progress by corresponding notches in the upper and lower edges of the abutments of the bridges of bone that confine the marrow. They are seen in Fig. 48, page 207, and are designated by the dotted line continued from *d*, across the hole for passage of the vertebral artery (460). These notches

enclose spaces much larger than the nerves which occupy them, so that in health they are not endangered by the motions of the spine: but when the periosteum of the vertebra becomes inflamed and swelled, in rheumatism or other diseases, the nerves are often most painfully compressed, and, perhaps, irritated. According to the nature of the disease and the particular fibres most affected, we may have a neuralgia of the spine, spasms of the muscles, or palsy, with or without pain in the part affected. You have been told of the connexions between the spinal nerves and those of organic life, through the medium of the sympathetic nerve (304). Now the fibres of the latter which communicate with the spinal nerves are often interested in diseases of the soft parts about the orifices through which these nerves leave the spinal or vertebral canal. Hence, disorders of internal organs often connected with affections of the periosteum and the fibrous tissues around it; and the most profound knowledge, coupled with sufficient experience, is required to trace the hidden chain of relation between complaints seemingly so dissimilar.

468. It is needless to describe particularly the general appearance of the *ribs*. A glance at either of the figures of the skeleton, or at Fig. 49, which represents the bones of the chest, will give clearer ideas than pages of description. The ribs are twelve in number on each side. They form curious double joints with the spine, being articulated

Fig. 49.



Bones of the Chest.

with the bodies of the dorsal vertebræ by a small head on the extremity, and with the transverse processes by a smooth prominence at a short distance from the head. These joints permit them to rise or fall at their anterior ends, but confine them to a fixed position posteriorly. They do not encircle the entire circumference of the chest: for, in front of that cavity you see the *sternum* or *breastbone*, occupying the middle portion of its walls.

469. The bony portions of the ribs do not reach the sternum, but you observe in Fig. 49, a white portion extending from the extremity of each rib towards the latter bone. These are called the *cartilages of the ribs*, but they are really composed of bone in that condition in which it is found in some parts of the skeletons of children, and in the whole osseous system of certain fishes (159). The flexibility of these cartilages permits the ribs to rise and fall in the act of breathing; and as the sternum is supported upon them, as if on springs, it shares in all their motions.

470. Sometimes, in old age, the cartilages of the ribs become ossified, and their motion is then destroyed. You will naturally ask how the individual can breathe under such circumstances. The explanation is the more important, because a silly fashion or criminal vanity often leads the young and beautiful to imitate this deformity of age by artificial means. I shall enlarge upon this subject hereafter.

471. The sternum (Fig. 49, *a*), is composed of several pieces in early childhood, but rarely fails to become united into one, before the growth of the frame is complete. It extends downward from the throat to the bottom of the chest, in front of the lungs and heart. In general form, it resembles the blade of an antique Roman sword, placed with its hilt at the hollow of the throat, and its point at the pit of the stomach. It is tipped with gristle at its lower extremity, which is called by anatomists, *the ensiform or sword-shaped cartilage*. The angles of the hilt of the sword support the inner extremities of two long and slender bones of the shoulder, which you can readily feel in your own person stretching along

the front of the base of the neck (Fig. 46, *h*,—Fig. 47, *e*, pages 190, 191). These are called the *collar bones* or *clavicles*; they form the only bony connexion between the superior extremities and the trunk.

472. The sternum appears suspended from the cartilages of the seven superior ribs (Fig. 49): The three next ribs are attached by their cartilages to that of the seventh; and the two lowermost are merely tipped with gristle, and are connected with the sternum only by muscular fibres. The superior extremities are suspended upon the sternum by means of the clavicles (471); and the articulations of the ribs being moveable behind at the spine, the weight of the whole chest and arms tends to drag the ribs downward and contract the chest.

473. The few muscles attached to the spine and the posterior ends of the ribs near the joints, are too weak to resist the whole weight of the chest; and those of the breast, though they may draw the ribs nearer together or toward the shoulder, cannot, *of themselves*, elevate the chest, because they are attached at both extremities to moveable parts—that is, to the ribs and to the shoulder. Now, the chest must be elevated during inspiration, or the man cannot breathe; and it is evident that this can only be effectually accomplished by means of bands or props running from the chest or shoulders to the head or cervical vertebræ. The muscles of the neck, then, are the principal support of the chest, and are directly interested in elevating the ribs and shoulders during inspiration. Their action must be very much increased when there exists “a difficulty of breathing.” But you know that when muscles are much exercised they grow larger, and when kept unnaturally at rest they lose their tone. Please to hold this in mind for a few minutes.

474. You see that the ribs resemble hoops, all leaning downward in front, the lower being much more oblique in their position than the upper ones. As the back ends of the ribs cannot rise, because they are closely articulated with the spine, it is the front of the chest that

must be alternately lifted and depressed in breathing. When the hoops rise, it is very plain that the sternum must be thrust further from the spine, particularly at its lower end, where, from the greater length and obliquity of the ribs, the increased size of the chest in inspiration is greatest. Providence designed this portion of the chest to be the largest in circumference, as you may judge by a glance at the skeleton (fig. 46); but many silly people think it would have been much better formed had it been made the smallest.

475. Now, suppose you were to employ a tight ligature or band to bind the ribs and sternum firmly towards the spine, so that it should be difficult to breathe: would you not expect the muscles of the breast to be weakened by unnatural rest, and those of the neck enormously enlarged by continual exercise?

476. There is a very wide but thin cutaneous muscle on each side of the neck, the model of that with which a horse shakes flies from the neck by twitching the skin. In man it is generally useless, few persons having the command of its action. But when the breathing becomes very difficult, this feeble muscle involuntarily endeavours to assist in elevating the chest, useless as its efforts must be—for it belongs more properly to the skin, and all its attachments to the parts within it are merely cellular, except at one spot where it has a fibrous connexion with the side of the lower jaw. This muscle is broadly attached to the skin of the breast at one extremity, and to that of the face, particularly about the angle of the mouth, at the other. When called into action, this muscle gives a careworn expression to the cheek, and draws downward the angle of the mouth into an attitude of *grumness*.

477. Now, oblige me by reviewing the last five paragraphs, and then reply to a plain question. Why is it that a physiologist, when he sees a remarkably slender waist, accompanied by a neck distorted by large and wire-drawn muscles, small and high shoulders, and a sullen look in a face designed by Providence to be—*what I might have described when younger*--why is it,

I say, that he turns so sorrowfully away to muse upon the gross misapplication of so much mechanical genius?

478. I have said that the chest and shoulders are mainly supported and elevated by the muscles of the neck. But these muscles, being chiefly attached to the head, their action tends constantly to drag the head and the cervical portion of the spine forward towards the chest. It is therefore requisite that the head and spine should be kept erect, or the principal motion of the ribs in breathing will be very much limited. The manly port in an erect attitude depends chiefly upon the tone and action of the multitude of muscles of the back which originate from all the spinous and transverse processes of the vertebræ, running from one to another, and binding them strongly to each other, or passing on to be inserted into the back of the head. It follows obviously from these facts, that if disease or art should deprive the muscles of the back of their proper exercise, so as to enfeeble them, the due support of the head and spine must be lost, the muscles of the neck can no longer elevate or support the chest in a proper manner, and respiration must be imperfectly performed.

479. When you recollect that perfect respiration is necessary to perfect nutrition, that the muscles, like other parts, depend for their functional power upon a supply of pure blood, and that parts already weakened must suffer most from all causes of debility, you will at once perceive how a weakness of the spine and a limitation of the motion of the ribs, produced naturally or by the follies of fashion, mutually and rapidly increase each other until they terminate in the most terrible deformity and the utter destruction of health and comfort. Even a habitual stoop, and the custom of leaning over a desk in writing, are evidently primary causes of such evils, and the reason why they so often produce diseases of the lungs by limiting the exercise of their functions is equally plain.

480. The *pelvis*, the *basin*, or lower portion of the bony structure of the trunk, requires but a passing remark. It is formed of four bones, each of which is divided into

several portions in children. The first of these bones which I shall mention is the *sacrum*, seen at *t*, fig. 46. It is composed of five imperfect or false vertebræ, which are separate in childhood, but form a single piece in the adult. This bone is articulated, at its upper extremity, with the last lumbar vertebra. It represents an irregular inverted pyramid very much flattened on the anterior and posterior sides, and strongly curved, presenting its concavity forwards towards the cavity of the pelvis. The spinal canal is continued from the vertebræ, along the back of this bone, but near its lower extremity the spinous processes are wanting, and the canal becomes a groove. Four holes penetrate this bone, having small posterior and large anterior orifices, for the passage of some of the great nerves of feeling and voluntary motion coming off from the lower part of the spinal marrow. The sacrum is generally considered as a part of the spine by anatomical writers.

481. The *coccyx*, or *os coccygis*, is a small bone appended to the point of the sacrum, and seems to complete its curvature. It is altogether unimportant to us in the course of our present studies, and it is sufficient to name it, with the remark that it completes the spinal column, and is composed of several very diminutive false vertebræ united together.

482. With the sacrum and coccyx, the two *share* or *haunch bones*, called, very ridiculously, the *ossa innominata* or *nameless bones* by anatomists, complete the pelvis. You see their general figure, which is too irregular for description here, at *s*, fig. 46, and *j, j*, fig. 47. In childhood they are each divided into three bones, bearing distinct names, which it would only perplex your memory to mention. On the outer sides of these bones are two very deep cups of bone, lined with cartilage, each designed for the reception of the large round head of the corresponding *femur*, *os femoris*, or *thigh bone*, which with the cup forms the hip-joint.

483. Let us now take a hasty glance at the bones of the extremities. As it is not a part of my plan to enter more fully into the description of the anatomical struc-

ture of the human frame than is absolutely necessary for the purpose of rendering our physiological remarks intelligible, I shall not attempt to describe in words the general form of the bones of the extremities. All the knowledge requisite for our present purpose may be obtained from a hasty notice of their number and a few of their peculiarities. The figures of the skeleton presented at pages 190 and 191, will convey a tolerable idea of the dimensions and shape of each of these bones.

484. The upper part of the superior extremity, called the shoulder, is formed upon two bones: the clavicle or collar-bone, (fig. 46, *h*, fig. 47, *e*),—which is united with the sternum, as you have been already informed, by means of a moveable joint at its inner extremity,—is also articulated, at its outer extremity, with a large, broad, triangular bone, called the *shoulder-blade* or *scapula* (fig. 47, *f*). This joint is also moveable. The collar-bone acts like a lever. Although many strong muscles arising from the head, back, loins, and breast are inserted into the scapula, or into the arm, which is suspended from it, and although all these muscles, when in action, tend to draw the top of the arm and shoulder-blade inwards towards the spine, the collar-bone prevents them from accomplishing this purpose. All that these muscles can effect is, to raise or draw down the point of the shoulder, by tilting the clavicle, which is then made to move like the spoke of a wheel around its joint with the sternum, which may be regarded as the hub of the wheel. The arm, being thus kept continually at a proper distance from the side, has a fair chance of moving in all directions. It can strike a blow upon an object placed behind the person, and the hand is permitted to reach all parts of the back.

485. To convince yourself that this freedom of motion could not exist in the absence of a clavicle, you may watch the motions of the domestic cat—an exceedingly active animal, but one in which a very slender and flexible ligament supplies the place of the collar-bone. These animals can clasp a mouse or any other

object closely to their breast, and they can strike, most powerfully, downwards or inwards; but they can do no injury by throwing the back of the paw forward; and if an unwelcome visiter *should trouble them behind the ear*, they have no remedy but an awkward scratching with the hinder claws. Such is the case with all quadrupeds that seize their prey by leaping, and with others which require but little extent of motion with great strength in their anterior extremities.

486. On the back of the scapula, a little above the middle of the bone, you may see a strong, elevated ridge of bone, called *the spine of the scapula*, which rises higher and higher as it approaches the shoulder-joint (484), and terminates in a broad beak, hanging over that joint, and forming what we commonly call *the point of the shoulder*. This is the part of the bone with which the outer end of the clavicle is articulated; as has been already mentioned.

487. By glancing at *f*; fig. 47, you will observe that the sharpest angle of the triangle formed by the scapula is directed towards the shoulder-joint. It is placed immediately under the broad beak of bone mentioned in the last paragraph; and it terminates in a *process* or projection of bone shaped like the cup of the common plaything called a cup and ball. The cavity of this process, which is very shallow, is covered with cartilage. It is exactly fitted to the *head*, or round projection seen at the upper part of the humerus or bone of the arm (fig. 46, *i*, fig. 47, *g*), which is also covered with cartilage; and these two parts—the cup and ball—form the shoulder-joint.

488. The shallowness of this joint permits the bone of the arm to roll freely in the socket through more than the third of a circle upon its axis, and to point in all directions throughout about the half of a sphere, without calling for any motion in the elbow-joint. This is one of the most important advantages which man enjoys over the brute. But the same cause renders the arm very liable to dislocation, because the socket yields

very little support to the ball; and its security, therefore, depends almost exclusively upon the tonicity of the muscles and the strength of the ligaments.

489. The lower extremity of the humerus is much flattened before and behind, and extended laterally, so as to form two condyles, which, taken together, look not unlike a very short map wound upon its roller, the ends of which—to continue the figure—project a little, to furnish attachments for muscles, and set crosswise on the end of the shaft, looking towards its front side. Around the middle of the scroll there is an elevated ridge, separating the two condyles from each other, and both these prominences of bone are covered with cartilage, being designed to assist in forming the elbow-joint.

490. The forearm is constructed upon two bones, the *radius* and the *ulna*; both of which contribute to the formation of the elbow-joint. But the latter is much more extensively connected with the humerus than the former.

491. The *ulna* (fig. 46, *l*, fig. 47, *i*,) is thick and strong above, and tapers off till it becomes very delicate at the wrist. At the elbow it grasps the back part of the inner condyle of the bone of the arm, in much the same manner that a hand, with the fingers half closed, would grasp a roll of paper. The part corresponding with the ends of the fingers has a deep cavity formed for its accommodation, in the back part of the lower end of the humerus, so that when the forearm is fully extended, this projection of the ulna comes into contact with the bone of the arm, and checks further motion in that direction. On the contrary, the part corresponding to the heel of the hand at the wrist, projects a little, forming a point which is received into another shallower depression in front of the shaft of the humerus, just above the condyles, when the forearm is properly bent. This checks too great flexion of the arm.

492. The *radius* (fig. 46, *k*, fig. 47, *h*,) is slender above, and becomes thick and strong below, where it forms

nearly all the upper half of the joint of the wrist. Its upper extremity terminates in a thick ring of bone called the *head*, laid flat across the shaft, and covered with cartilage both on its edge and its upper side. The latter surface is hollowed out a little like a cup, and fits on to the outer condyle, thus contributing to form the beautiful but complex hinge of the elbow-joint.

493. When the palm of the hand is directed forwards, in what is called *the supine position*, the radius and ulna lie nearly parallel; but when it is directed backwards, or in *the prone position*, these bones are crossed upon each other like the legs, when one limb is thrown over the other as we sit on a chair. This twisting of the bones results from the lower end of the radius following all the motions of the hand, as it turns with it upon the lower end of the ulna, as on a pivot. In order to permit this motion, the edge of the ring or head of the radius is received into a corresponding excavation in the side of the upper end of the ulna, also lined with cartilage, and is there bound by a ligament that surrounds and embraces it. The lower end of the ulna, which is a little enlarged, so as to form a small head, is received into a similar excavation in the corresponding part of the radius; and thus the latter bone slides freely round it, as the position of the hand is changed.

494. The lower and larger extremity of the radius is slightly excavated and covered with cartilage, and part of the narrow end of the ulna is coated in a similar manner, for the proper construction of the joint of the wrist.

495. The wrist is composed of no less than eight small bones, (fig. 46, *m*,) which it is unnecessary and would be tedious to describe. They are united together by numerous joints and many powerful ligaments, which permit them to move upon each other to a certain extent, so as to contribute in a considerable degree to the incalculably numerous and delicate changes of form that render the human hand one of the greatest wonders of creative power. They are all collected into the space intervening between the wrist-joint and that part of the

hand where the wristband of the shirt usually terminates. Collected into one mass, called the *carpus*, they form, at their upper extremity, a regular arch, so fitted to the cavity formed by the ends of the two bones of the forearm as to complete the joint of the wrist; allowing the hand to be flexed or extended, or to rock from side to side as far as the neighbouring ligaments permit.

496. At the lower extremity of the united bones of the wrist the surface of the mass is very irregular, to form strong joints, with five small, long bones, called the metacarpal bones (fig. 46, *n*). These long bones may be plainly felt as they lie buried in the substance of the palm of the hand. The joints between the metacarpal bones of the fingers and the bones of the wrist enjoy but a very slight extent of motion; but the correspondent joint of the metacarpal bone of the thumb is much more free, permitting the ball of the thumb to roll forward, so as to be opposed to the palm. It is this that confers upon us the power of *grasping*, and enables us to practise a thousand mechanic arts which quadrupeds would never be able to acquire, even if they were endowed with human reason.

497. With the lower extremities of the metacarpal bones, and with each other, the long bones of the fingers and thumb form regular joints, having a hinge-like motion. The fingers have three ranges of these long bones, while the thumb has but two. The ranges are called *phalanges*, and the bones the *phalangeal bones*. It is unnecessary to describe their forms, which you can examine upon your own person. The phalanges are seen in fig. 46, *o, p, r*.

498. The whole number of bones above described as appertaining to each of the superior extremities is thirty-two; of which two belong to the shoulder, one to the arm, two to the forearm, and twenty-seven to the hand. Besides these, we often find several small bones, not directly connected with the skeleton, but buried in the fibres of some of the principal tendons, as they pass over the joints of the fingers or thumb. These are designed to serve as pulleys, and enable the muscles to act at a

greater mechanical advantage. In some instances they are coated with cartilages on the side next the corresponding joint, to the formation of which they then contribute.

499. Let us now proceed to consider the bones of the inferior extremities. These are so similar in their general arrangement to those of the superior extremities—the thigh answering to the arm, the leg to the forearm, and the foot to the hand—that it will be sufficient for our purpose to point out the principal points of difference

500. There are no bones in the lower extremity answering to the clavicle and the scapula. The manner in which the hip-joint is formed has been partly described already (482), and it only remains for me to mention that the cup-like cavity of the joint is very deep, embracing a considerable part of the ball or round head of the femur or thigh bone. It is called the *acetabulum*, or little vinegar cup, by anatomists. This arrangement permits the lower extremity to move in all directions, and to roll upon its axis, so as to point the toes inwards or outwards; but all these motions are much more closely limited than they are in the superior extremity, because the cup-like cavity of the shoulder joint is much smaller and more shallow than the acetabulum.

501. The head of the thigh bone is not seated directly on the shaft, like that of the arm, but is supported upon the end of a long portion of bone shooting obliquely upwards from the inner side of the shaft, and called the *neck of the femur*. You may see this arrangement very clearly portrayed in fig. 46, *u*, in the left limb.

502. As we advance towards old age, the neck of the femur gradually increases its angle with the shaft, until it approaches the direction of a perpendicular to the general course of the bone. When this change has been effected, the neck is much more liable to fracture from slight accidents, such as stepping suddenly from a high curbstone or carelessly descending a stairway. If you have been instructed in the first principles of the science of mechanics, you will be able to comprehend the reason of this fact; and if not, you will perceive at

once the importance of such knowledge to those who would understand their own personal interests; for all branches of science are so intimately connected that a knowledge of one of them throws light upon all the others. A fracture of the neck of the thigh bone rarely occurs before the age of forty years, and it is one of the most serious accidents of advanced life.

503. Sometimes the changes attending advancing age go further, and the neck of the thigh bone is absorbed. The head of the femur then rests directly upon the shaft, and the motions of the joint are very seriously limited. This change is one of the causes that produce the stiffness of motion in extreme old age, and contributes, together with the shortening of the neck (501), to the diminution of stature observed at the same period of existence.

504. The head and neck of the femur, like the lower extremity of the same bone, and, indeed, all the extremities of all the long bones, are spongy or cellular in their structure—a point which I must request you to bear in especial remembrance.

505. The thigh bone tends obliquely inwards and downwards from the hip to the knee-joint; and near the latter it is expanded, so as to produce two very large condyles, forming the upper half of the knee-joint.

506. The leg having two bones, (fig. 46, *v, w*, fig. 47, *n, o*.) like the forearm, it is right to remark that only one of these bones, called the tibia, (fig. 46, *w*, fig. 47, *n*.) contributes to the formation of the knee-joint. It is very thick at its upper end, but becomes narrower below. The other bone of the leg, which is thin and delicate, is called the fibula, (fig. 46, *v*, fig. 47, *o*.) Unlike its prototype, the radius (492), its lower extremity assists in forming the ankle-joint, but its upper end is articulated with the tibia at a point entirely below the knee, and enjoys exceedingly little motion.

507. The two condyles of the femur fit accurately into two corresponding depressions in the head of the tibia, and thus form the chief part of the knee-joint. But there is a third bone interested in this structure, called

the *patella*, which means a little shield. It is commonly called the *knee-pan*. You see it represented in fig. 46, in front of the knee-joint. The patella is not directly connected with the skeleton, but lies buried in the tendon of the principal muscles which straighten the leg. These muscles, by means of their tendon, are inserted into its upper side; the tendinous fibres penetrate its substance; and many of them, passing beyond it, are inserted into the front part of the head of the tibia. The patella, therefore, acts like a pulley, to give a greater mechanical advantage to the action of the muscles. Its inner surface is lined with cartilage, and contributes, with the tibia and fibula, to form the joint.

508. Though the tonicity of the very large muscles surrounding the knee-joint gives very considerable support to the bones of the leg, very strong ligaments are also required to prevent injury from too sudden shocks, to which the lower extremities are continually subjected. The perpendicular attitude of the leg and the obliquity of the thigh produce such an effect, that in all falls upon the feet there is a disposition in the femur to tilt outwards; and consequently the inner side of the joint is much more liable to sprains than the outer. It is therefore provided with a very strong lateral ligament on that side. In violent leaps, or other feats of agility, this ligament is occasionally strained; and such accidents give rise to a most troublesome lameness, which sometimes proves incurable.

509. The ankle-joint has little power beyond the simple hinge-like motion, which allows the foot to be flexed or extended. The other motions of the foot, complex and beautiful as they are, result almost exclusively from the joints connecting with each other seven spongy bones, called *the tarsal bones*, (Fig. 46, *x*. Fig. 47, *p*.)

510. These tarsal bones, viewed as part of the frame of the lower extremity, correspond with those of the carpus or wrist (495) in their relative position; but they are much larger and less numerous, for there are but seven instead of eight of them. One of them is principally concerned in completing the ankle-joint, and an-

other forms the heel. I might dwell for hours upon the wonderful motions of the many joints of the *tarsus*, but our subject and our plan will not warrant the indulgence.

511. The bones in the lower extremity answering to the metacarpal bones of the hands are called *the metatarsal bones*. These, with the phalanges of the toes, are similar in number and general form to the corresponding parts of the superior extremity.

512. As the bones corresponding to the scapula and clavicle are wanting—as the number of bones of the tarsus is one less than that of the carpus—and as the patella is a bone peculiar to the knee-joint, the whole number of osseous pieces in each inferior extremity is thirty (498).

513. The skeleton, constructed as I have represented, would fall to pieces at once, when placed in an erect attitude, if the bones were not held together by strong attachments. The ligaments contribute to prevent such a catastrophe very essentially; but as these organs are long enough to permit all the necessary motions of the joints, and do not contract like muscles, they can only prevent the parts of the skeleton from separating widely from each other, and cannot of themselves preserve the upright and correct position of the frame. This duty is performed by the muscles, which, passing from one bone to another, and being always in a state of tonic contraction while we are awake, effectually prevent any very material bending of the trunk or limbs without the permission of the will.

514. In falls from a considerable height, or when we step suddenly down a stair or over a curbstone, the jar would be felt very severely even by the head, if there were no provision to deaden the force of the blow. Take two or three marbles, such as are used by children at play; range them in a row, so that they may touch each other, and let a companion steady them in that position by placing a finger over each of them; then place another in contact with the last of the series, but do not confine it with the finger. Things being thus prepared, if you roll another marble against the first of

the series, the last will fly off with nearly as much force as your blow has impressed. This is a property of all elastic bodies, which is commonly illustrated, in schools that teach mechanics, by means of a number of ivory balls suspended upon cords, as probably you have seen. If you try the same experiment, after substituting a little ball of hard dough or other inelastic matter for one of the marbles held under the fingers, the last of the series will hardly move at all. Now, ivory is the most perfectly elastic of all known substances;* and the more solid parts of bone very closely resemble ivory. If, then, all the pieces of the skeleton were composed of solid bone, a jar received upon the feet would be transmitted from one bone to another, until the last of the series, which is the cranium, would feel almost the whole effect of the blow; and a fall upon the feet would then be nearly as dangerous as a fall upon the head. Under these circumstances, the thin bones of the cranium, being ill adapted to sustain such violent concussions as are often met with in the necessary accidents of life, would yield readily to such forces, and most of us would be killed by fractures of the skull and injury to the brain before we had passed the period of infancy.

515. To prevent these evils, and for other equally wise purposes, the bodies of the vertebræ (459), the condyles of the occipital bone (428), the extremities of all the long bones (389), and nearly all the thickness of the bones of the tarsus (509), are of a loose and spongy texture, so that these parts act like balls of dough interposed between the marbles in our experiment (514), and effectually prevent the transmission of violent jars from one portion of the skeleton to another. In yielding this security, they are aided very much by the elastic cartilages which form the surfaces of all the moveable joints.

516. An additional protection to the head results from the curved form of the spinal column (fig. 44), which

* Elasticity is not measured by the distance to which you can bend a body without preventing it from returning to its original form, but by the suddenness with which it regains its first position, when indented or bent. A body may be both highly elastic and very brittle, like glass.

being composed of many moveable pieces, supported in their erect position by the tonicity of numerous muscles, acts like a double spring between the head and the pelvis, to break the force of falls: for the muscles yield a little to sudden extension, and immediately recover themselves under the action of the will; thus allowing the spine to bend and return again, very gradually, to its proper form.

517. A similar arrangement is noticed in the structure of the chest (fig. 49), for the protection of the all-important organs contained in the cavity of that part of the body.

518. The ribs (*c, c, c*), though literally long bones, have no medullary cavity (390), but are composed of a net-work of osseous fibres or cells in the interior, with a very thin covering of not very solid bone. The sternum (*a*) is of a similar structure. The cartilages of the ribs which connect the anterior extremities of those bones with the sternum, and which are seen, unmarked by any letter, (between *c* and *a*.) are very elastic. If a blow be struck upon the breast bone, part of its force is lost in compressing the soft texture of the sternum; another part in the bending of the cartilages. If the blow be very severe, the bony portions of the ribs act like dull springs; so that the force must be very great before it can seriously injure the organs within the cavity.

CHAPTER XI.

OF MUSCULAR STASIS OR EQUILIBRIUM.

519. As the proper position of the various parts of the skeleton, and, consequently, the attitude of the figure of an individual, depends upon the proper balance of action between the different muscles, it follows that any thing which disturbs that balance must modify the atti-

tude. If the cause which produces this modification be permanent, the figure will be inevitably changed.

520. But you have been told that when a part is exercised regularly and within certain limits, it increases in size and strength. You have also been informed that when a part is kept in idleness its nutrition is diminished, and it becomes weaker, or loses its power altogether.

521. Any thing that improperly exercises or renders idle a part of the frame, must destroy the proper balance of action between that and other parts, and a certain degree of deformity must necessarily result.

522. Now, apply these principles to the management of the muscular system. We commonly use the right arm most frequently; hence it is generally larger and stronger than the left, which is a deformity. But we are more frequently called upon to apply force in exertion upon things placed in front of the body than upon those placed behind it; and we more frequently draw things towards us than we thrust them from us. Now, when we draw a thing towards us, we generally support the weight of the body on the right leg, or keep it in reserve to prevent falling backward if our hold should slip. In applying to the ground the force required to give effect to the pull, the left foot is chiefly used. Try this upon a rope, and you will perceive what I mean. For this reason our left is generally stronger than our right leg.—Another deformity. As the right arm and shoulder are stronger than their fellows, we are naturally inclined to use them in heavy pushing, and our principal force is then naturally applied by means of the left leg. This increases the deformity.

523. Boxing for boys, and battledoor for girls, are well adapted to the correction, in part, of the error of form that has just been described; for they call the right leg into unusual exertion, and thus promote its development.

524. Persons who are left-handed naturally, or become so by habit, undergo changes of figure exactly the reverse of those just pointed out. Thus, you perceive that by unduly strengthening any particular set of muscles

connected with the skeleton, we necessarily produce more or less deformity, and a long series of alterations often follows, until the whole appearance of the person may be modified. This principle explains the peculiar marks by which we can often tell at a glance to what trade or profession an individual has been educated.

525. But the loss of power in any set of muscles by inactivity or disease, is productive of equally remarkable changes which are effected on the same principle, and can often be predicted by an accomplished surgeon who possesses physiological tact. For instance : if a child be labouring under the deformity called club-foot, and the affection be confined to the right limb, he cannot readily support his person on the right foot, nor can he use the left for the proper efforts in applying forces by means of his right arm. The right lower extremity being thus rendered in great degree useless, all the powerful exercises that the unfortunate individual is capable of taking are performed on the left side of the body ; and consequently, the whole of the right side of the person, together with the bones themselves, soon loses its proper tone, and finally becomes diminished in size for want of the proper stimulus to nutrition. Such is the actual condition of most persons in whom we notice the deformity just mentioned.

526. But the evil stops not here. For want of proper support on the right, the body rests on the left foot, and of course the pelvis is bent or tilted downwards on the former side. But this throws the whole upper part of the figure so far to the right that the individual would inevitably fall over if the spinal bones of the lumbar region did not curve themselves so as to bring the upper part of the body into an erect position. Thus begins a curvature of the spine. But if the shoulders be carried far to the left in order to balance the weight of the right limb, the neck must take an opposite curvature to restore the perpendicular position of the head. Thus the spine is bent, *laterally*, into the form of a letter S. Even the dorsal portion of the spine (458) partakes of these

changes. But the dorsal vertebræ cannot be bent laterally to any considerable extent without changing the relative positions of the ribs: they will be thrust nearer together on one side, and unnaturally separated on the other. The form of the chest is thus essentially altered, and the functions of its contents embarrassed.

527. These false attitudes being frequently and necessarily assumed, the bones, ligaments and muscles become adapted to their new relations. Those muscles which are relaxed contract by their tonicity, and after a time become really shorter, in consequence of a modification of their nutrition; while those which are extended beyond the proper point are exhausted, lose their tone, and become attenuated, like an overwrought operative. All the energy of the will can not then enable the individual to restore the spine to its correct position, even for a single moment. It remains displaced, like a bone that has been long dislocated, and for the same reasons.

528. I might follow the train of unfortunate circumstances portrayed in the few last paragraphs much further, but it is sufficient for my present purpose to explain how vast are the evils which may follow so simple an accident as the partial loss of the use of one foot in childhood. Now, although these changes are rarely carried very far in most cases of club-foot, yet their presence, to a certain extent, is traceable in every case. The side affected is always wasted, and the spine is always more or less serpentine. You will immediately infer, from the foregoing details, that even slight derangements of the balance of muscular action, or, as it may be properly termed, *muscular stasis*, are productive of danger to health as well as strength, and must ultimately overthrow our comforts and shorten our lives. Let us apply this principle to the solution of some of our ordinary habits and their consequences.

529. Until recently, all our schools were furnished with stools divested of backs, for the use of the children. It was thought that this promoted the formation of a good figure! "Sit up straight and hold your shoulders back" has been the universal order; and the endeavour

to support such an attitude has been continued under *magisterial jurisdiction* for many hours in each day. Now, no muscle can endure very long continued exertion without intervals of rest; as I have remarked in a former chapter. Of course, then, after a few minutes, the child, endeavouring to sit erect on one of these instruments of torture, finds the muscles on the back of the spine exhausted. They yield, and he stoops, until the ligaments of the vertebræ are put upon the stretch so as to relieve the muscles. The body then forms an arc, or bow, with the concavity forward. This embarrasses his breathing, and a severe oppression and a propensity to sigh soon shew the evils likely to result from such a false position. But even the temporary relief obtained from this yielding of the spine is denied, in most instances, by the watchful oversight of the preceptor. "Sit up straight or you will spoil your figure, Miss A—!" "Hold up your head and *open your chest*, or you will ruin your health before you finish your studies, Master B—!" Such are the orders, and the sufferer endeavours to comply. What is the consequence? The muscles of the back of the spine being utterly incapable of keeping the column erect for more than a very few minutes at a time, the student relieves himself by resting first upon one hip, then on the other.

530. Now, as far as the spine is concerned, a person sitting nearly erect upon one hip, is in exactly the condition of the child who has a club-foot on the opposite lower extremity. The pelvis and the vertebræ are twisted in exactly the same manner (526). The muscles of the spine on one side of the column are nearly at rest, while those of the other side are put to unusual exertion. If the weight of the body be regularly and frequently thrown, first upon one hip and then on the other, an imperfect amount of rest is obtained; and although the respiration is not entirely free, and any liability to disease of the lungs already existing is increased, there is little danger of serious deformity from this habit.

531. But the nature of the school studies does not permit the pupil to repose alternately and equally upon

each hip. The right hand is usually employed with the book or the pen, and then the pupil invariably rests upon *the left hip*. The consequences of such a habit are evidently such as would follow club-foot upon the right side, except that the right arm being chiefly exercised, while the left arm is scarcely employed, the former is increased in size and the latter enfeebled. The curvature of the spine takes place in both cases alike.

532. But during writing lessons, as ordinarily practised, the student always rests his left arm upon the desk; and he naturally assumes the same position in reading, when permitted to do so. Let us examine the consequences of this position. The left shoulder is thrust upwards, and the muscles which draw it downwards are called into active exertion to support the weight of the body, while those which elevate it, or, in other words, those passing from the head and the vertebræ of the neck to the clavicle and scapula are relaxed, and kept in an unnatural state of rest. The former are, therefore, unduly increased in strength, while the latter are proportionally enfeebled.

533. The moment that a student who has long persevered in the bad habit just described attempts to sit erect, or to rise from the desk, the left shoulder falls too low for want of support. This defect explains the reason why the dress is so apt to slide from the left shoulder in a majority of carefully educated females; and it adds to and materially accelerates the progress of the deformities pointed out in the last few paragraphs. But our space will not allow me to dilate any further upon this most important subject; and it would require a far more thorough knowledge of anatomy than belongs to an elementary education, to enable you fully to comprehend its details.

534. In order to avoid the vices of figure just pointed out, it is necessary that the seats for pupils in schools should be provided with backs, and that the students should be permitted *to use them*. In writing, if the lessons be long continued without relaxation, the pupil should be furnished with a desk nearly or quite horizon-

tal, and should sit with the right side to the desk. The paper should be placed in advance of the person; the body should be reclined a little backward, and the attempt to lean over the paper ought to be immediately checked. Long continued standing in classes should be prohibited, and the student ought to be allowed to stand at ease on each foot alternately. The drilling of young children, like troops in line, for hours together, is extremely injurious, and confinement for a long time to a given attitude as a punishment, is a proof of profound ignorance of the laws of life.

535. An habitual stoop is chiefly the result of either the undue strength of the muscles on the front of the spine, which bend the column, or the undue weakness of those of the back of the spine, which should hold it erect. The rational modes of cure are those which tend to strengthen the latter muscles by moderate exercise, without fatigue; *for fatigue always weakens a part instead of strengthening it.*

536. Now nothing is more common than the attempt to cure a stoop by Minerva braces, or bands designed to draw the shoulders backward, and nothing is more likely to occasion or increase a stoop. These braces support the shoulders in the required position, as long as they are kept in action; and, consequently, the muscles which should effect this support, and which are already enfeebled, are relieved from all exertion. Under these circumstances they grow continually weaker, and the moment the brace is removed the stoop reappears more remarkably than before.

537. The proper mode of curing a stoop is to apply forces occasionally, and for a reasonable time, calculated to draw the shoulders forward. This proceeding obliges the muscles passing from the spine to the scapula or shoulder-blade to exert themselves in resisting these forces, and consequently they increase in strength; so that, when the forces are removed, they draw the shoulders backward. To convince yourself of this fact, you have only to compare the figure of a servant accustomed to carrying a heavy tray with that of a soldier of the

ranks, whose profession obliges him to attend drill and march under the weight of a knapsack. The moment the former deposits the tray he becomes remarkably erect, and his shoulders are firmly braced: the instant the latter casts off his knapsack, he stoops and becomes round-shouldered.

538. I will give you but one more illustration of the deformity produced by undue exercise of particular muscles, leaving you to apply the principles already explained to the practical business of life, as your age advances, and as the extent of your reading on anatomical subjects increases.

539. When you study optics, you will learn that the human eye is so constructed that it must vary its shape continually, according to the distance of the object upon which the attention is directed; for the eye, like a magnifying glass, has its focus. Now you know that when a magnifying glass is intended to have great power, it is made very convex. When it is very convex you must place an object very near the lens, in order to see it distinctly; and the distance at which the object should be held in order to be seen is inversely proportionate to the convexity of the lens;—it is called the focal distance.

540. Now, when we look at a distant object our eyes require to be made less convex, and when the object is more near, they must become more convex in order that we may see plainly. The power of effecting these changes resides in the straight muscles of the eye (Fig. 27, *a, b, c, d*, p. 93). These muscles arise from the back part of the orbit of the eye, and running forward so as to embrace the eyeball above, below, and on each side, are inserted by means of broad tendons into the outer coat of the eye near the edge of the clear part, called the *cornea*, through which we receive the light. These muscles are of the mixed class, (138) being partly under the control of the will, and partly involuntary. When we are called upon to look at a near object, their tonicity is increased without our consciousness; they contract, and by pressing firmly upon the eyeball, make the front of the eye more convex and prominent. This is

one reason why the eyes ache so severely when we gaze for a long time at minute articles held very close to our faces. On the contrary, when we look upon very distant objects, the muscles lose their tone, become relaxed, and the eyeball expands by its elasticity; thus rendering the cornea flatter and less prominent.

541. The necessity for using spectacles with convex glasses in old age results chiefly from a flattening of the front of the eye, owing to a loss of tone in the muscles; and short-sightedness or nearness of sight in the young is generally the result of bad habits at school in very early life, though it frequently occurs naturally from original defects either in the tone of the muscles or the form of the ball. If a child be employed many hours in the day in reading and writing at the desk, or studying in a small room—if he be deprived of the opportunity of recreation where he can gaze at distant objects, the constant exercise of the straight muscles of the eye in lessening the focal distance soon gives them undue strength, and they become incapable of relaxing sufficiently to allow the patient to see any thing distinctly that is placed beyond the distance of a few feet. Shortness of sight, when the result of habit, may be cured by proper muscular exercise, if attended to at an early age; but as it is the involuntary power of the muscles that produces the deformity, it is the involuntary power that must be exercised to remove it. And how is this to be accomplished? Simply by making efforts to see distinctly objects placed beyond the acquired focal distance of vision. This will exercise and strengthen the peculiar involuntary function of the nerves supplying these muscles, by which the latter are left free to relax themselves, and their tonicity, being less frequently called into exertion, they become weaker and *therefore more useful*.

542. Most persons who are very short or near-sighted will be found affected with *strabismus* or *squinting*, and I will explain the reason. We always look at an object with both our eyes on all ordinary occasions; and, consequently, the lines of the direction of the sight in the

two eyes are not parallel to each other. Both lines tend to a point at the object. Now, in looking at a fixed star, the sun, or any other very distant object, the obliquity of the eye is too slight to be perceived: but take a bright button, or any other small body, and bring it gradually nearer to the nose of one of your playmates. Tell him to look at it, and you will perceive that the nearer it approaches, the more he will squint. He cannot possibly look at any thing with both eyes without squinting sufficiently to bring them both to bear upon it. The obliquity of the lines of sight is of course the result of an involuntary contraction of the internal straight or rectus muscles of the eye (fig. 27, *b*); and if the individual be in the constant habit of gazing at his books, his papers, or the things immediately around him, these muscles are very apt to become even stronger proportionally than the other recti muscles. The habit of squinting is then established, and unless treated very early, cannot be relieved by any kind of exercise. Fortunately, it has been recently discovered that this deformity, so extremely disagreeable when very considerable, may be readily cured by a surgical operation that is neither very painful nor dangerous. It consists in cutting a passage about half an inch deep from the front of the eye into the orbit, between the ball and the nose, then taking up the internal rectus muscle on a silver hook, and cutting it off with sharp scissors. The other muscles are capable of effecting all the necessary motions of the eye, by the aid of the oblique muscles, one of which you have seen at *e*, fig. 27, and the deformity is immediately much diminished, or entirely removed.

543. Squinting is not generally the result of bad habits. It is more frequently a mark of a faulty construction of some part of the nervous system, frequently within the brain; and it oftens proves hereditary. But these circumstances do not necessarily prevent the operation above mentioned from curing the mechanical difficulty in the motion of the eye. Again; temporary squinting is occasionally an important symptom of func-

tional disorder in the brain, and can only be successfully treated by the cure of the disease on which that disorder depends — a disease that may be seated originally in any part of the body, while the brain is merely affected by sympathy with that part, through the mediation of the nerves.

544. A man who squints, sees distinctly with one eye only — namely, that which is directed properly to the object of his attention. The other receives and conveys a very obscure image. He cannot judge well of distances; and as the obliquity of vision is rarely equal on both sides, he soon becomes accustomed to the exclusive employment of the better eye alone. The other then gradually loses its powers for want of use, and often becomes much smaller by a diminution of its nutrition; for, as you have been led to conclude from former remarks, little care is taken in preserving the existence of organs that are no longer of use. The heart, the blood-vessels, the nerves, and the absorbents have enough to do without supplying food to agents that will not work. If they do not let them absolutely *starve*, it is only because there still may be some hope of ultimate improvement. *Even those that cannot work* share the same fate, and in this respect the operations of the vital functions seem to have set a bad example to society, which, I am sorry to say, is but too closely followed by those who govern our public charities. The operation already described leads to the speedy removal of the evils mentioned in this paragraph, by bringing the bad eye into action, improving its function, and inducing its developement.

545. Unequal action of the recti muscles of the two eyes often brings about a difference of the focal distances: one becomes nearer sighted than the other, and, as they do not agree, the habit of using only one eye at a time is established from this cause. If the patient uses glasses, he then requires them to be of different powers in order to see distinctly. This is unfortunate, though it might be remedied in early youth by a proper course of gymnastics of the eye. I might write

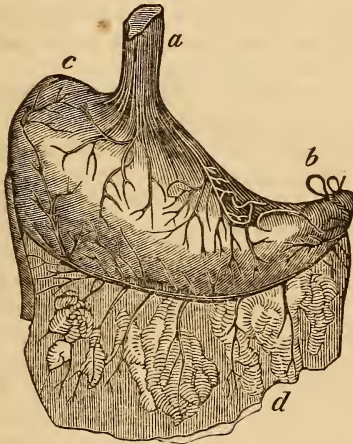
a volume on this novel subject to advantage, but it would be wrong to do so in an elementary work. You have the general principles laid down in the beginning of this chapter, and if you reason logically in applying them to actual circumstances, you will draw conclusions as accurate as any I could give you, and much more accurate, I trust, than most that you will find in books. There is no branch of human science as yet so perfected that a logical reasoner with moderate powers and tolerable industry may not contribute essentially to its perfection.

546. It is now time to give you a very few hints as to the application of the same principles to the action of the involuntary muscles. These belong, as you will recollect, to those parts of the frame which perform the functions of organic life; and they are chiefly found about the digestive apparatus. For the most part, their fibres are arranged in the form of a coat or layer around hollow organs, to enable them to press upon, to move, or to expel their contents; and the manner of their arrangement has been already described in the chapter on the surfaces of the body. The tonicity of the fibres of these muscles is so great that, when the cavities of the organs which they envelope are empty, they generally contract so as to close those cavities; but when any thing is admitted in the cavities, the fibres are put upon the stretch, or, in other words, they are exercised. But I shall be better understood by making reference to a particular case.

547. Fig. 50, represents the human stomach covered with serous membrane, as will be described hereafter. The end of the œsophagus is seen at *a*; at *c* you observe the upper extremity of the stomach where the food enters; and at *b*, the lower extremity, from which it passes into the intestines after it has been prepared by digestion. The whole stomach is enveloped in a coat of muscular fibres running round it in various directions, as has been already mentioned,—(368, 373). Now, at *b* there are a number of circular fibres embracing the outlet, which are much stronger than those found about other parts of the sto

mach. They close the stomach entirely at this point, except when they are relaxed to permit the chyme to pass. This outlet of the stomach is called the *pylorus*, and it is seen very distinctly in Fig. 54, at *c*, the stomach being laid open in that figure.

Fig. 50.



548. When food is taken into the stomach, the pylorus immediately contracts; for undigested food is a strong stimulus to the muscular fibres of that part; but the other fibres allow themselves to be stretched, so as to enlarge the cavity. These latter then press gently upon the food, and as the mucous coat of the stomach gradually dissolves the food into chyme, they move it from place to place by a kind of serpentine motion, so as to bring one portion of undigested matter after another within the range of action of the mucous coat, in order to be digested. When any portion of chyme approaches the pylorus, it soothes the fibres and they relax, so as to permit the prepared matter to pass through under the gentle pressure produced by the tonicity of the stomach in general; but the moment undigested food presents itself

there the pylorus is firmly closed, and the food is compelled to return by the serpentine motion until it is completely dissolved. Thus the fibres of the pylorus and those of the rest of the stomach antagonise each other.

549. There are many other hollow organs in the body, such as the gall-duct, for instance, which are provided with muscular fibres at their outlet, arranged in the same manner and exercising functions similar to those of the pylorus. Such muscles, (for they are sufficiently distinct from the neighbouring fibres to be regarded as separate organs,) are termed *sphincters*.

550. When a hollow muscular cavity like the stomach is frequently over-distended, the fibres of the walls of the organ are over-exerted, and consequently, their tone is lessened. *They may even be paralysed*, but then death soon closes the scene. Now, when they are thus exhausted they cannot properly perform their functions. In the case of the stomach, the food is not digested in proper time, and the sphincter being constantly stimulated by the presence of crude matter, also becomes exhausted by over action, and ceases to exercise its proper guardianship; ill-digested particles then find their way into the intestines with the chyme, and produce irritation and disease. Need I say any thing further in explanation of this cause of dyspepsia from excessive eating or drinking? Some of the worst cases of dyspepsia are occasioned by a habit of drinking immoderate quantities of cold water in childhood, when there is no fever or other unusual cause of thirst to require it. Moderation in all things is necessary to health.

551. The effects of food or drink of a character too stimulating, do not differ very essentially from those of milder articles taken in excessive quantities; but in this case it is the nerves that are exercised too much, and the muscular fibres lose their tone from the weakening of the nervous influence. The same result may follow a blow upon the back which jars the spinal marrow. What think you then of the wisdom of an empiric, who advertises some single remedy for dyspepsia, regardless

of the thousand causes of such affections,—of which causes I have named but three?

552. With these remarks I quit the subject of muscular stasis or the balance of muscular action, having endeavoured to give you those general ideas which will render your future reading and reflection on such matters easier and more profitable.

CHAPTER XII.

OF THE GREAT CAVITIES OF THE BODY.

553. As the walls of the great cavity of the head, containing the brain, are entirely composed of bone, their outline and the general form of the cavity have been described in the chapter on the osseous system, (chap. x.) But the thorax or chest, and the abdomen with its appendage, the pelvis, are but partially surrounded by bone, as you have been informed in the same chapter. I now wish to give you an idea of the manner in which the walls of their cavities are completed.

554. The spaces between the ribs, (fig. 49, *c, c, c,*) are occupied by muscular fibres arranged in two sets, so as to form two muscles. One set run obliquely downward from the lower edge of one rib to the upper edge of that next below. The other set pass obliquely upward from the upper edge of one rib to the lower edge of that next above. Thus the walls of the thorax in the intervals of each pair of ribs are completed by two thin layers of flesh. These are called *the intercostal muscles*, and it is their function to draw the ribs nearer together and lessen the intercostal spaces. They belong to the class of the mixed muscles, being governed by the will and partly involuntary.

555. A great many powerful and broad muscles originate from the spine and the back of the occipital bone, and cover the back of the chest, running to be

inserted into the scapula or the bone of the arm. They draw the arm or the shoulder backwards when called into action, and they very greatly increase the thickness of the fleshy walls of the thorax. A part of one of the largest of these muscles supports the scapula, and, by that means, the whole upper extremity; though it is assisted in this duty by many others passing down from the back of the head or the spinous processes of the cervical vertebræ to the scapula, the clavicle, the sternum, and the uppermost ribs.

556. On the front of the chest, the fleshy walls are also strengthened in a similar manner, chiefly by three large muscles originating from the ribs or their cartilages and the sternum, and passing, two to the scapula and one to the bone of the arm. These muscles draw the arm or the shoulder forwards. There are also a great many other muscles connected with the structure of the chest, but I do not mention them because I am not writing upon anatomy. Enough has been said for our present purpose.

557. You now understand how the sides of the chest, seen at fig. 49, are completed, but you perceive that it is still open at the top and bottom. Between the uppermost dorsal vertebra, *b*, and the two uppermost ribs, *c, c*, there is a small round opening corresponding with the base of the neck, through which you might readily pass your arm into the cavity within the ribs. This space is filled up by the muscles of the neck originating from the clavicle, the sternum, the two uppermost pairs of ribs, the transverse processes of the spine, &c. (555), by the gullet or œsophagus which conveys the food to the stomach, the trachea or air-passage to the lungs (250), and the great arteries, veins, nerves, &c. passing to and from the head, combined with the cellular tissue and fat binding these various parts together.

558. But at the lower end of the thorax, corresponding with the outline of the false ribs (472)* and the ensiform cartilage, you see the chest widely open towards what was described to be the abdomen in the com-

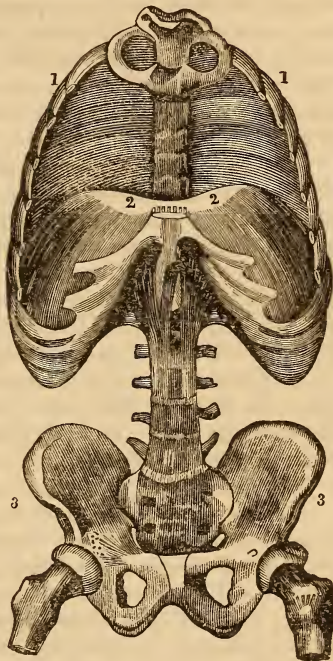
* The false ribs are those whose cartilages do not reach the sternum.

mencement of the last chapter (324). And how is this opening closed, so as to make the chest a separate cavity from the abdomen?

559. In fig. 51 you are presented with a front view of the trunk of the body laid open so as to expose the cavity of the chest by the removal of the sternum and the cartilages of the true ribs. The upper or first pair of ribs being naturally provided with little if any cartilage, appears as a pair of perfect bones. The fleshy and bony walls of the chest are seen at 1, 1.

560. At the numbers 2, 2, you see a broad, thin muscular organ called the *diaphragm*. It is this which completes the division between the thorax and the abdomen. It arises, by tendinous fibres, from the front of the spine in the lumbar region, and by fleshy fibres from the cartilages and bones of the

Fig. 51.



Section of the Great Cavities.

false ribs as well as from the ensiform cartilage. The middle of the diaphragm, where the figures are placed, is composed of tendinous matter, and the whole constitutes a broad, thin, complex muscle, forming a division between the cavities of the chest and abdomen. It is penetrated by the œsophagus on its way to the stomach, by the aorta (264) conveying the blood towards the lower extremities, and by the ascending vena cava

(263) and the thoracic duct (197) on their way towards the heart.

561. The diaphragm may be readily compared to an inverted basin, its bottom being turned upward into the thorax while its edge corresponds with the outline of the lower edges of the false ribs and the sternum. Its cavity being directed towards the abdomen, it enlarges that cavity very much at the expense of that of the chest, which it contracts to an equal extent, as you see in fig. 50.

562. Having now completed our view of the walls of the thorax, it will be proper to say something of its principal contents. The cavity of the chest is almost exclusively occupied by the right and left lungs (249), the heart, and great vessels (264). The heart is situated between the two lungs, but extends much farther to the left than the right, thus rendering the left lung smaller than its fellow. The heart reposes upon the upper surface of the diaphragm, with its point far to the left and near the front of the breast, where we feel it beating, between the ribs. Its auricles are directed towards the right and backwards.

563. Now both the lungs and the heart are almost constantly in motion, and would be embarrassed or injured by friction against neighbouring parts were they not protected by a peculiar arrangement. You have read of the synovial membranes, which are designed to protect the articular cartilages against friction (172), and something resembling these are furnished to all organs contained in the great cavities of the body. They are termed *serous membranes*, and contain nothing but a little *serum*, much like that highly fluid portion of blood in which the red coagulated portion floats in the bowl a few hours after bleeding, or that fluid which fills the cells of the cellular tissue in common dropsy.

564. It is usually considered extremely difficult to convey a clear idea of the arrangement of the serous membranes by means of words or drawings; but I must endeavour to do so by resorting to a very homely comparison. Suppose a common pillow-case sewed up

into a sac, to represent a serous membrane, and your clenched fist to be an organ requiring such a protection. Thrust your fist into one end of the sac, so as to invert the latter, as we sometimes invert the finger of a glove. Your hand is now in nearly the same condition with an organ covered by its serious membrane. It is not *in the pillow-case*, but is surrounded by it; and if you rub the hand thus enclosed against any hard substance, you find it in great degree protected from the friction by the sliding of the outer over the inner layer of linen that covers it. But usually the layer of serous membrane next the enclosed organ adheres firmly to its surface, as the corresponding layer of the pillow-case would adhere to your hand if it were covered with tar. You have only to conceive then, that the pillow-case is moistened within by a very little fluid, and you have a tolerable picture of the arrangement under description. Every organ has blood-vessels, nerves, &c., and most of them have ducts passing to and from them. Now these never penetrate a serous membrane, and must find their way to the organ through the opening by which we suppose it thrust into the inverted sac; and in our little experiment, they may be represented by your arm, as it passes in to join your fist within the sac.

565. Each lung has its distinct serous membrane, called a pleura, which adheres to its surface, and then envelopes it, as in a bag. The outer part of the pleura adheres to the corresponding side of the cavity of the chest, and to the upper surface of the diaphragm, furnishing them with an extremely thin, transparent, and beautifully smooth lining. At the middle of the chest, the two pleuræ come together, forming a kind of double membranous partition passing from the sternum to the spine, and dividing the cavity into two apartments.

566. But the two layers of the partition are separated widely from each other in front, to accommodate the heart, which, being provided with its own peculiar serous membrane, called the pericardium (see fig. 34, page 127), occupies a third chamber in the thorax.

The two layers are separated near the spine to accommodate the great blood-vessels and other important parts.

567. The trachea having divided into the two bronchiæ, one of these enters the substance of each lung, attended by the necessary blood-vessels, nerves, and lymphatics, and is then distributed in the manner already described at page 123.

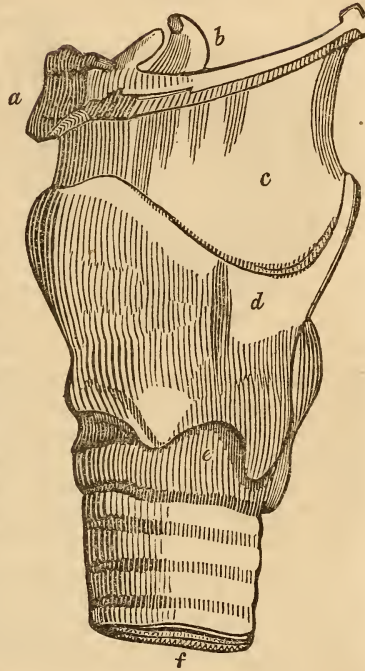
568. The lungs and heart fill up nearly the entire cavity of the chest. The former, being in communication with the external air through the open canal of the trachea and the mouth and nose, are kept always in contact with the walls of the cavity by atmospheric pressure, dilating and contracting as the ribs rise and fall in breathing. If a wound should penetrate the cavity, the air is admitted into the serous sac of the pleura, and the lung on the injured side being equally pressed upon by the atmosphere on the outside and the inside, immediately becomes collapsed, arresting the breathing on that side, and leaving a large empty space between its surface and the ribs. Were it not for the partition formed by the pleura across the middle of the chest, both lungs would be collapsed; and if the patient were not immediately relieved by art, he would inevitably die in a few minutes.

569. Before speaking of the abdomen, which must be described presently in order to enable you to comprehend the mechanism of breathing, I will seize this opportunity to say a few words about an important appendage to the trachea:—the organ of the voice, called the *larynx*.

570. In Fig. 52 you are presented with a view of the upper extremity of the trachea, at *f*. Above this you see a superstructure, somewhat complex in its arrangement, which occupies the throat, between the root of the tongue and the middle of the neck. This forms part of the tube through which the air is inhaled to the lungs, and it is composed of six cartilages. The first of these, which is marked *e*, is called the *cricoid cartilage*. It is little more than an enlargement of the uppermost ring

of the trachea, but it is essentially changed in shape, being much broader at its posterior part than it is in front. It encircles the tube completely. Seated upon this ring, like a saddle placed on end, with its seat presenting forward towards the throat, is the thyroid cartilage, *d*, the upper and angular point of which forms the projection vulgarly termed Adam's apple. The thyroid partially embraces the cricoid cartilage with what may be compared to the flaps of the saddle: but you will better understand this arrangement by referring to Fig. 53, in which the larynx is represented as it would appear to

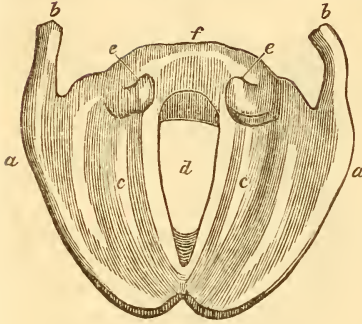
Fig. 52.



an eye looking down perpendicularly into the wind-pipe.

571. In figure 53, *f* represents the high posterior part of the cricoid cartilage; *a, a*, the thyroid cartilage, partly embracing the former, and rising high above it; *b, b*, two horns or processes projecting back from the sides or flaps of the thyroid; *d*, the passage for the entrance of the air into the trachea, called the *glottis*; and *e, e*, two other small cartilages of the larynx, called the *arytenoid cartilages*. These last are articulated by moveable joints upon two little prominences on the back part of the upper edge of the ring formed by the cricoid cartilage. From the bases of the arytenoid cartilages,

Fig. 53.



tendinous chords are stretched forward to the front angle of the thyroid just below the notch, which you perceive in the middle of its upper edge. These chords are seen shining through the mucous membrane close to the side of the glottis, in Fig. 53. They can be tightened or relaxed by means of

a number of beautifully delicate muscles, passing from one to another of the cartilages of the larynx, and thus the pitch of the voice is elevated or depressed. For these chords act like those of a violin, and are made to vibrate by the air in such a way as to produce the tones of speech and song. This fact will explain to you the reason why the compass of the voice can be so much increased by well regulated training. The muscles of the larynx may be enlarged and strengthened by exercise, like all other muscles; and thus the art of elocution, so far as the voice and gesture are concerned, becomes a branch of gymnastics.

572. The mucous membrane lining the trachea lines also the cricoid cartilage, then sweeps through the glottis, covers the vocal chords, and sinks down for a short distance between these chords and the flaps of the thyroid cartilage, so as to form the two little pockets marked *c, c*, Fig. 53. The membrane then lines the inside of the thyroid, and, rising above its upper margin, is continued into the pharynx and the mouth.

573. At *a*, Fig. 52, you see the body of a curious bone called the *hyoid bone*, which gives attachment to the root of the tongue. It has two long horns projecting backwards, which correspond pretty nearly in their

course with the appendage of the thyroid, but lie some distance above that cartilage.

574. The mucous membrane, in its course to the mouth, fills up the space between the edge of the bone and that of the cartilage, as you perceive at *c*, Fig. 52. When we "get a drop the wrong way," it is received into one or other of the pockets at *c*, Fig. 53, where it causes much irritation, and is displaced with difficulty by coughing. Thus, the larynx is in a manner suspended upon the hyoid bone, and is compelled to follow all its motions. The bone itself is suspended upon two long flexible ligaments coming from the base of the cranium, but all its other connexions with the skeleton are merely muscular, and bind it chiefly to the lower jaw. It moves with every motion of that most moveable of organs, the tongue, and as constantly influences the position of the larynx. This will explain one principal reason why inflammations of the larynx are so fatal to orators, ministers, lawyers, and others who are compelled to speak frequently and for hours together. The inflamed part can scarcely know any rest in persons of these professions.

575. In the act of swallowing, the food passes over the top of the larynx on its way to the pharynx and œsophagus; and, were there no arrangement to prevent such consequences, the exquisitely sensitive edges of the glottis that guard the entrance to the lungs would be liable to perpetual irritation. The sixth cartilage of the larynx affords this necessary protection to these parts. It is called the *epiglottis*. In form it resembles the leaf of a tree, and is attached by its stem to the notch in the middle of the upper edge of the thyroid cartilage.

576. The position of this leaf is nearly perpendicular, and it stands up in the throat, just behind the root of the tongue, with its back towards the mouth and its front towards the glottis. You see the point of the epiglottis just peeping above the body of the hyoid bone at *b*, Fig. 52. It may be seen during life, in some individuals, when the base of the tongue is depressed by a spoon or the finger. Now, when the food leaves the mouth, on

its way to the œsophagus, this leaf is shut down, like a lid, over the glottis, and completely protects it from irritation. Sometimes it acts irregularly, and then we very readily "get a drop the wrong way."

577. Referring once more to Fig. 51, you observe how very incomplete are the bony walls of the abdomen. Bounded above by the hollow of the diaphragm, it has the five lumbar vertebræ behind, and the bones of the pelvis or basin (3, 3) below. Between the lower margins of the false ribs and the upper edges of the ossa innominata (482) no bone is visible. The pelvis is surrounded and inclosed by many muscles, which thus complete the walls of the abdomen in that direction, and it is by muscles and their tendons that the wide open space represented in the figure between the edges of the ribs and the pelvis is filled up. It is only necessary to glance at four pairs of these organs in this volume.

578. Three pairs of very broad, thin muscles, are connected with six or eight of the lowermost ribs above, with the spine behind, and with the edge of the pelvis below. These muscles coming from each side of the loins meet, and are inserted *into each other* in front, in such a manner as to embrace the sides and the anterior part of the abdomen with three distinct layers of flesh and tendon. The innermost pair is composed of fibres passing directly round the body, so that almost their only action is to compress the contents of the cavity which they surround. The fibres of the second pair run obliquely upwards from the upper edge of the pelvis and the lower part of the spine towards the middle line of the abdomen, where they meet and mingle with their fellows from opposite sides, and the upper portions of these muscles are inserted into the cartilages of the seven lowest ribs and the ensiform cartilage. Of course, when they contract, they not only compress the abdomen, but draw down the ribs and sternum; thus assisting in the process of breathing. The fibres of the third or outer pair run obliquely downwards from the eight lowermost ribs, and from the highest part of the upper edge of the pelvis, and intermingle, like those of the second

pair, with their fellows from the opposite sides. These muscles also assist in drawing down the ribs in breathing.

579. The two last mentioned pairs form very broad and thin tendons, instead of fleshy fibres, over the greater part of the front of the abdomen, so as not to increase unnecessarily the thickness of the walls of the cavity. These tendons, by a peculiar arrangement, which it is not necessary to describe, form two long, tendinous sheaths, running from near the lower end of the sternum down to the upper edge of the pelvis, one on each side of the middle line of the abdomen. In these sheaths are enclosed two long, thick and powerful muscles, which connect the cartilages of the three lowest pairs of true ribs with the front of the pelvis. They are designed to bend the body forwards. These eight muscles, together with many others about the spine and loins, complete the fleshy portion of the walls of the abdomen.

580. It is now time to enumerate, with a few comments, some of the principal organs contained in the abdomen. Its cavity is lined throughout by a thin serous sac, like the pleura in the chest, but it is called the *peritoneum*. One side of this sac adheres firmly to the fleshy walls of the abdomen, including the under surface of the diaphragm, and the other is thrown over the front of a large number of important organs called, collectively, the *abdominal viscera*, all of which are thrust against the back or the upper part of the peritoneum, so as to invert it, as the lungs and heart do their proper serous membranes (564), and thus they all furnish themselves with a partial or complete covering of serous membrane, commonly called their peritoneal coat.

581. Some of these organs, such as the small intestines, invert the sac so far that they become completely hidden, as a child's marble may be in the indented finger of a glove. In such cases the two sides or folds of the reversed portion of the peritoneum come nearly together behind the included organ, and, by adhering to the walls of the abdomen at the spot where the organ is supposed to be thrust in, they bind it to the sides of the

cavity, acting like a ligament, while they allow it to swing or move freely within certain limits. But these folds always leave space enough between them, filled with loose cellular tissue, to accommodate the blood-vessels, nerves, &c. belonging to the organs.

582. Others of these viscera, like the liver and part of the great intestine, revert the peritoneum far enough to cover the chief part of their surface with serous membrane, but leave a portion of their substance in contact with the fleshy walls, to which they are so closely bound down that they enjoy very little motion.

583. Others again, like the spleen and pancreas, are covered on their front side by the peritoneum, which is only slightly indented by them. These organs are not allowed to change their place at all under any circumstances.

584. But the most curious of these arrangements is seen in some of those organs that vary much in size at different times, and yet require a certain degree of freedom of motion. The stomach is one of these, for it is greatly enlarged by eating, and becomes very small when empty. If such organs were bound down to the sides of the abdomen by the peritoneum as firmly as some that have been mentioned, the membrane would be burst when the organs become distended. To meet this difficulty, the inverted portions of the peritoneum about the stomach and some other parts of the alimentary canal are much more extensive than necessary for the accommodation of these parts in their common condition, and then hang down from their front edges like aprons, placing them very much in the condition of a very small body in the inverted finger of a very large glove, and leaving them free to dilate to almost any extent. In the figure at page 239 you see this arrangement, where *c* represents the free duplicated part of the peritoneum hanging from the great arch of the stomach. In this figure all the front part of the peritoneal sac which lines the walls of the abdomen is of course removed, in order to display the stomach.*

* I am well aware of the extreme difficulty of giving a clear idea in

585. You will observe, if you have comprehended the three or four last paragraphs, that when we cut into the cavity of the peritoneum, from the front of the abdomen, the viscera appear as if they were all contained in that cavity, as in a sac; but, in reality, they are behind it, because the peritoneum, instead of enclosing them, is merely thrown over them like a wet pillow case, with its posterior side folded about them so as to embrace each of them more or less completely. You will also observe that the abdomen has but one serous chamber, while the chest has three (565, 566). Let us now describe the position of some of the principal abdominal viscera.

586. The liver is the largest gland in the body. It fills up very accurately all the cavity of the diaphragm on the right side (see Fig. 51), and extends over on to the left side to a point nearly half way between the point of the ensiform cartilage and the edges of the false ribs. Being very thick behind, it tapers to an edge in front; and being very bulky on the right side, it is also bevelled off to an edge on the left: so that it is placed very obliquely, and at least three-fourths of its substance lies under the false ribs on the right side of the abdomen. Its front margin corresponds very nearly with the outline of the cartilages of these ribs, and crosses to the left about the point of the ensiform cartilage, terminating nearly under the spot where the number 2 is seen on the left side of the diaphragm.

587. As the left lung fills up the space seen between the convexity of the diaphragm on the left and the corresponding ribs—as the point of the heart is found with a portion of the right lung in the same relative position on the right—and, as the liver fills up considerably more than one half the great cavity of the basin of the diaphragm (561), it follows that a small sword passed horizontally through the body, between the uppermost

words of the arrangement of the serous membranes, and diagrams are of scarcely any assistance in the attempt. Fortunately a thorough knowledge of the subject is not very essential to the general student, and I must leave it to the intelligent and well-informed preceptor to illustrate it more perfectly by models or actual specimens, should he deem it of sufficient importance to his class.

of the ribs, might penetrate the lungs, the heart, and the liver; nothing but the diaphragm being interposed between these important organs. The sword, in this case, would pass just above the stomach, which fills up the chief part of the basin of the diaphragm on the right side, being in contact with the lower surface of the liver, which is rather concave, and accommodates it beautifully.

588. The liver is divided into several lobes. Into the fissures between them, the blood-vessels and nerves enter, and from one of them the gall-duct comes out. You have been told that the liver is an organ appropriated to the secretion of bile. On its under, concave surface, you find the gall-bladder, or sac, designed to retain the bile until it is wanted in the progress of digestion.

589. Just below the stomach, on the left side of the spine, but within the cavity of the abdomen, we find a curious organ called the spleen. In bulk, when in health, it may be compared to the hand of a stout man, though it is much thicker and not so long. It is not a gland, for it has no secretory duct; but it is composed, in a great degree, of blood-vessels. In the absence of all certain knowledge of its functions, we have been in the habit of considering it as a kind of receptacle for the surplus blood called to the internal organs when they are brought very actively into play, whether in health or disease (274), and it certainly seems well calculated for such a purpose. In attacks of disease attended with great determination of blood towards the abdomen, the spleen is known to become distended with blood; and when chills of intermittent fever have continued for a long time, it is not unusual for it to become permanently enlarged to a great extent, constituting what is called, in vulgar phrase, *an ague cake*.

590. But the chief purpose of the existence of the abdomen is in the accommodation of those organs which are interested in the great process of digestion, and it is time for me to describe the route of the alimentary canal which fills by far the greatest portion of the cavity.

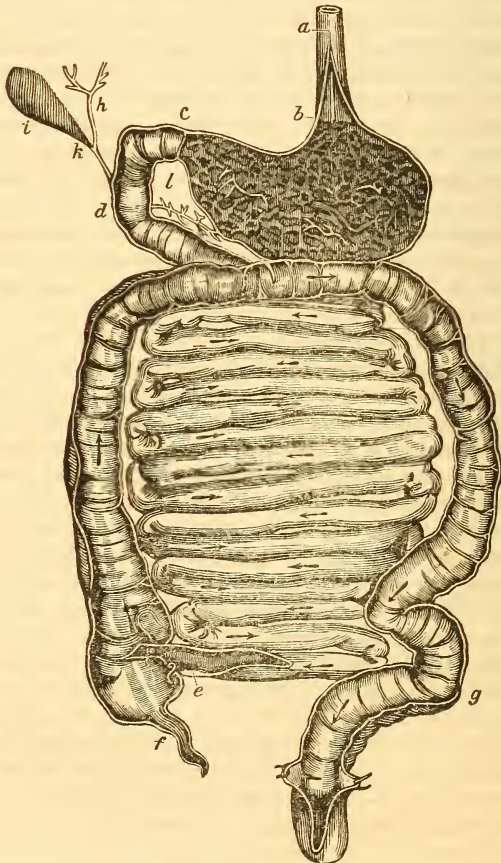
591. The œsophagus (fig. 54, *a*), almost immediately after passing through the diaphragm, expands itself into a large cavity resembling, in some degree, a chemist's retort. This is the stomach, and the extremity by which the œsophagus enters it is called the *cardiac extremity*. You have been already informed, that the epithelium or cuticle terminates at this spot, and you see this termination clearly represented at *b* in the accompanying wood-cut, where the comparatively smooth lining of the narrow canal gives place to the corrugated mucous membrane of the stomach, which is well displayed in the figure; for the stomach is there drawn as if one half of it were removed to show the interior. At the other extremity *c*, you observe the sphincter or pylorus, which prevents the food from leaving this cavity until its nutritive portions are converted into chyme. The figure represents the parts thrown far from their natural position, in order to enable you to distinguish the different portions of the alimentary canal, which are so obscured in their ordinary arrangement, that one part conceals another from the view.

592. The stomach stretches itself, like a bridge, obliquely across the spine just below the liver, so that its cardiac extremity is placed somewhat to the left of the vertebral column and its pyloric orifice is situated a little lower down, and on the right side of the spine.

593. The pyloric extremity opens into a long, narrow tube, called the *small intestine*; the first portion of which *d* extends nearly in a horizontal line from right to left, crossing the spine in its course, and bound firmly to the posterior part of the walls of the abdomen by the peritoneum. From the circumstance that this portion of intestine is about twelve fingers' breadth in length, it is termed the duodenum. It is a most important part of the digestive apparatus, for it is here that the biliary and pancreatic fluids are mingled with the chyme, to effect that more perfect assimilation which prepares it to be taken up by the lacteals. At *h*, you observe a portion of the biliary duct with some of its branches coming from the liver, where the bile is secreted. At *i*,

you have the gall-bladder, which contains the bile till it is wanted in the intestine; and *k* represents the commencement of the duct which conveys it to the duodenum. At *l* you see the duct of the pancreas, with some of its branches, carrying a fluid similar to the saliva to be emptied into the duodenum along with the bile.

Fig. 54.



594. From the left extremity of the duodenum, the alimentary canal is continued in the form of a very long, narrow tube, commonly known by the name of the small intestines, and arbitrarily divided into two portions, distinguished by the special names with which I do not think it necessary to charge your memory. The small intestines are thrust so far within the duplicature of the posterior side of the peritoneal serous sac that they are entirely enveloped by it, and stand at a considerable distance from the walls of the abdomen. They have, consequently, so much freedom of motion that they sometimes get entangled with each other, or with other parts, giving rise to very dangerous accidents.

595. It is in the small intestines, chiefly, that the chyle is separated from the chyme, and absorbed by the lacteals; and to facilitate this process, the mucous membrane of this part of the canal is rendered a great deal longer than the cellular and muscular coats; so that it is thrown into numerous circular folds, which, in some places, hang over each other like the shingles on a roof, giving ample space for the absorbents to act on the food as it passes, and preventing the escape of any nutritive particles.

596. After wandering about in the abdomen through a long course, marked in the figure by the arrows, the small intestines at length terminate in the *great intestine* at *e*. The sides or walls of the small intestine here project in a singular manner, into the cavity of the great intestine, so as to hang somewhat loosely in two festoons, forming a very curious valve, on the same principle with those already noticed as belonging to the veins.

597. The small intestine, instead of opening directly into the end of the great intestine, penetrates its side at the distance of a few inches from its extremity, and the part of the latter which projects beyond the orifice, is called the *cæcum*. At *f*, you see a little appendage to the *cæcum*, of which the intention has never been discovered. It is called the worm-like appendage, or *apendicula vermiformis*.

598. The cœcum is situated in the hollow of the right os innominatum (482), where it is bound firmly down by the peritoneum. From this point, the great intestine, taking the name of *colon*, runs upwards on the right side of the spine until it reaches the posterior edge of the liver. Throughout this part of its course it is firmly bound down by the peritoneum, but it then springs in a very wide arch horizontally over the front of the abdomen to the left side, passing along very near the anterior edge of the liver, a little below the ensiform cartilage, and in front of the stomach when that organ is empty, and returning nearly to the left side of the spine. During this part of its course it enjoys considerable latitude of motion. The disease called colic, generally consists in a spasmodic affection of the muscular fibres of this part of the colon. From the point last mentioned, the great intestine runs down on the left side of the spine, bound down pretty firmly by the peritoneum, until it comes near the upper margin of the pelvis, where it winds itself into the form of the letter S, forming what is called the *sigmoid flexure of the colon*, g. At the extremity of this flexure, it descends in a nearly straight line into the pelvis, and is called the *rectum*.

599. Having now completed all that it is necessary to say as to the position of the abdominal viscera, it is right that I should notice a remarkable peculiarity of their circulation. The blood conveyed to these organs by the arteries does not return immediately into the veins of the general or nutritive circulation, like that of other parts of the body (264). On the contrary, the veins originating from the viscera, are all gradually collected into one great venous trunk, called the *portal vein* or *vena portæ*. This vessel conveys the blood to the liver, and there divides, like an artery, into a peculiar set of capillaries. It is from these vessels, *filled with venous blood alone*, that the bile is secreted; and this is the only instance in which a secretion is formed from the veins. After the blood in the portal capillaries has performed its office, it is received into another set of vessels, called the *hepatic veins*, which carry it back into the

vena cava, where it again enters on the route of the general circulation.

600. One of the principal ingredients of the bile is carbon;—the very impurity of venous blood that is chiefly discharged from the body by means of respiration. Thus you see that the liver and the lungs are occupied in performing, to a certain extent, the same office, and this explains the reason why any disease of one of these organs is so apt to produce disease of the other; for the healthy organ is then obliged to perform extra duty.

601. There is another peculiarity of the veins of the *portal system*, as it is called, that is worthy of notice. They are not provided, like other veins, with valves.

602. The whole amount of blood contained in the blood-vessels of the abdomen and thorax is very great, forming no inconsiderable portion of that which supplies the whole body; and this fact is of great importance, as you will presently perceive.

603. When an individual is using great muscular exertion, in running, leaping, or lifting heavy weights, the muscles of the chest and abdomen are thrown into violent action, and they necessarily compress the great cavities of the trunk with considerable force. This compression squeezes out from the portal and other internal vessels a large portion of their blood, which must find accommodations in the blood-vessels of other parts. Hence the redness of the skin, the flush of the face, the veins ready to burst upon the forehead, the blood-shot eye and the giddiness of head attendant on excessive exertion. Men have been known to drop down dead with apoplexy while attempting to raise great weights. The quantity of blood forced from the chest and abdomen has proved too much for the delicate vessels of the brain; they have yielded, and inevitable death has instantly succeeded.

604. Now what opinion can you form of the reasoning faculties of one who has been informed of these facts, and still continues to encase the chest and abdomen in a tightly drawn garment of complicated canvass, wood, steel and whalebone, in order to improve upon

the model on which Providence has formed the species, —the form which the Creator made in his own image? What must be the consequence of a perpetual compression depriving the digestive and respiratory apparatus of their proper supply of blood, while it forces this fluid in inordinate quantities into the capillaries of the brain, leaving it to stagnate there by suppressing the freedom of the circulation? Excuse me if I prove a little severe, but the question should be answered. If constitutional silliness be not the first cause of tight lacing, the continuance of this folly will assuredly produce that undesirable accomplishment in a reasonable time, by depriving the brain of its proper exercise and nutriment. Corsets, properly regulated, and worn during certain portions of the day, may be both useful and necessary in certain stages of disease, deformity or debility, but those who wear them tightly laced for the purpose of improving a natural figure, are excusable only on the ground of a species of ignorance which a very slight knowledge of physiology must inevitably dispel. Among the evils following this abominable habit and dependent upon the effects of pressure just described are, indigestion, the conversion of a beautiful colour into a red and glaring spot upon the cheek in which the distended and diseased veins are distinctly visible, habitual inflammation, weakness and discoloration of the eyes, melancholy, distressing headache, and even swelling of the feet. Of other evils following the same custom, I shall have occasion to speak hereafter, though the catalogue seems long enough already.

CHAPTER XIII.

OF THE MECHANISM OF BREATHING.

605. THE process of breathing consists of two parts, the inspiration or inhalation, and the expiration or exhalation—terms needing no definition. In the effort of inhalation, the cavity of the chest is enlarged by muscular action, and the air rushing in through the trachea, expands the lungs to an equal extent. In exhalation, the chest collapses, partly by its own weight, and the air is forced out again through the trachea. But this process is also aided by the muscles, and in rapid or difficult breathing, the muscular action is all important and often very powerful. Let us examine the history of these processes.

606. The spine being supported and the head held erect by the muscles of the back, the two upper ribs, the sternum, and the shoulders are properly supported by the muscles passing from the head and the cervical vertebræ. When we perform an easy inhalation, these muscles contract very gently, and the ribs, sternum, and shoulders are slightly elevated by their action. As the ribs tend obliquely downwards (474), they cannot be thus elevated without widening the distance between their cartilages and the spine, and carrying the sternum also forward. This evidently enlarges the cavity of the chest, but only to a very slight extent.

607. But while the muscles of the neck are thus contracting gently, the intercostal muscles are also in action. The second pair of ribs is drawn a very little nearer to the first, and all the succeeding pairs must rise with it. Now, while this is going on, the third pair are drawn nearer to the second by the same means, and of course all the succeeding pairs are elevated again by this contraction. That is, the third pair is elevated

about twice as far as the second. Now as the same kind of contraction takes place throughout the whole series of twelve ribs, it is evident that the lower pairs of ribs are elevated many times farther than the first pair. But the lower ribs are placed much more obliquely than the upper ones, as you may perceive by reference to Fig. 49. page 211. The former pairs must therefore sweep much more widely from the spine as they rise than the latter ones. Thus, the lower part of the chest, where the principal bulk of the lungs is formed, is much more considerably dilated in inhalation than is the upper part. Now as the sternum must follow the motions of the cartilages of the ribs on which it hangs, it is tilted forward very much at its lower extremity, while its upper end remains almost at rest.

608. You perceive at once, then, that every thing which binds the lower ribs must interfere much more seriously with breathing than a similar restraint near the summit of the chest. But if you wish to ascertain how important is the motion of even the upper portion of the thorax, you have only to sit for half an hour leaning over your desk, with your head bowed forward, so as to relax the muscles of the neck, and thus deprive the superior ribs and sternum of their natural share in the process of breathing, and if you do not feel prompted, by that time, to *sigh* over your error, there is little dependence to be placed upon physiological laws.

609. But the ribs and sternum, with the muscles attached to them, are not the only parts interested in the effort to inhale. You remember the position of the diaphragm, placed like an inverted basin projecting into the chest from the edges of the false ribs, the spine and the ensiform cartilage, with the lungs and heart lying on its upper surface, and the liver and stomach filling up its cavity. This great muscle, which, while the lungs are empty, projects very high into the chest, as it is represented in Fig. 56. 1, 1, contracts on the instant of inhalation; and, driving the abdominal viscera and dragging the heart and pericardium downwards, renders the abdomen more prominent, as it is represented

in fig. 55, 2. To permit this change, the abdominal muscles are relaxed during inhalation. The contraction of the diaphragm flattens the basin or renders it more shallow, and brings it to the position seen in fig. 55, 1, and the cavity of the chest is thus enlarged to a great extent, as you may perceive by comparing the two accompanying figures with each other.

Fig. 55.

Fig. 56.

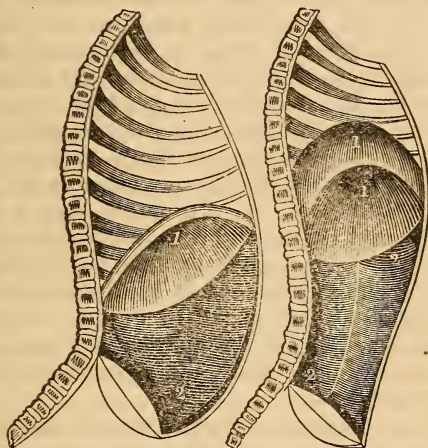


Fig. 55. Antero-posterior section of the thorax when the lungs are distended.

Fig. 56. Antero-posterior section of the thorax when the lungs are empty.

1, 1. The diaphragm. 2, 2. The muscular walls of the abdomen.

610. Having now described the mechanism of inhalation, let us consider that of exhalation. The inhaled air having answered the purpose for which it is admitted, and being charged with moisture and carbonic acid, requires to be expelled. For this purpose, all the muscles previously called into action are relaxed; the weight of the chest drags the ribs downward and contracts the cavity; this change is aided by the tonicity of the abdominal muscles, now no longer resisted by the activity of the diaphragm, and the abdominal viscera are forced upward by the pressure resulting from this

tonicity, and thus the depth of the basin of the diaphragm is rendered as great as before, and the heart is elevated to its former position. In other words, the form of the abdomen and thorax is restored from the condition represented in fig. 55, to that displayed in fig. 56.

611. Thus you see that the muscles of the abdomen are not less interested in respiration than those of the chest, and that neither of these sets of organs are capable of acting with full effect unless those of the neck and back be also in a healthy condition and in a proper attitude. A disease of the spine that compels a patient to curve the back, or a habitual stoop, are calculated to injure health and enfeeble the mind by embarrassing the process of respiration, and thus rendering impure the blood which nourishes the frame, supports its functional powers, and stimulates the brain to full activity. Even the motions of the abdominal viscera and the heart, produced by the rise and fall of the diaphragm, promote digestion and give vigour to the circulation. I mention these circumstances as illustrations of the manner in which one part of the frame depends upon another, and in proof of the complexity of those seemingly simple functions with which the ignorant so often venture to tamper.

612. When respiration is rendered difficult by disease, the abdominal muscles are often much more powerfully exerted in effecting exhalation. If the intercostal muscles be attacked by spasm, as is the case when we are affected with what is called "a stitch in the side," the breathing is carried on by the diaphragm; and this is also the case when the cartilages of the ribs become ossified in old age. On the contrary, in some rare cases, the diaphragm labours under rheumatism or nervous disease; and the patient, who then suffers excruciating agony upon every motion of the muscle, endeavours to keep it at rest, and breathes almost exclusively with the ribs and sternum. When any of the more important abdominal viscera are inflamed, the same effort is made to prevent the diaphragm from disturbing the inflamed part. Such diseases of the abdomen may be sometimes detected by the short, quick, and imperfect

breathing, even when the patient is deranged or insensible. In these cases, the muscles of the neck act powerfully in the endeavour to raise the upper ribs, and even the countenance is distorted by the exertion.

613. If the ribs be confined by a tight garment, it is obvious that respiration must be carried on by the diaphragm alone; and, by a law with which you are already familiar, this must give that muscle undue strength, while it weakens the intercostal and other muscles of the chest (475, 476). The moment the garment is removed, the ribs feel the want of proper muscular support, and fail to perform properly their function in assisting to support the sternum and the spine. In consequence of this the shoulders fall, and the back becomes distorted. When the habitual pressure is very great it even modifies the form of the ribs, indenting them or producing a narrowness of the lower part of the chest, which for ever forbids that perfect respiration necessary to vigour either of body or mind.

614. But the corset, so universally employed as an article of female attire, is made to embrace the abdomen as well as the thorax, and when at all tightly laced it must inevitably prevent those changes in the position of the abdominal viscera (609) without which it is impossible for the diaphragm to descend, and thus all the parts interested in the process of inhalation are seriously embarrassed in their action. The effects of this embarrassment are obvious to all well-informed observers in the straining of the neck, and the laborious heaving of the shoulders, which betray the folly if not the wickedness of the victim of fashion. It is impossible for the blood to be properly purified under such circumstances, and in addition to the evils already pointed out when considering the effects of pressure on the great cavities (603), I may mention that many of the nervous affections, such as neuralgia and even convulsions, so often witnessed in young females, are caused or very much increased by the action, upon the nervous system, of the impure blood thus forced into circulation.

615. One of the worst consequences of the habit of tight lacing, is the seeming necessity of continuing the use of the corset at all times, whether in full dress or undress. By preventing the proper motions of the abdominal muscles and the diaphragm, this instrument enfeebles those important organs and diminishes their tone. Immediately upon its removal, therefore, the diaphragm descends, and fails to support the heart in its proper position. Hence occurs a dragging sensation or that of heavy weight in the chest, generally accompanied by distressing palpitations. Meanwhile the abdominal viscera not being compressed sufficiently by the walls of the cavity in which they are placed, perform all their functions imperfectly. Hence follow indigestion, lassitude, and a long train of highly dangerous results, driving the patient to the reapplication of the cause of all this mischief.

616. Without prohibiting the proper use of the corset under surgical advice in certain cases of debility, and bowing to the conventional regulations which render its moderate use indispensable when in full dress, I would urgently recommend the gradual relaxation of the cords of those who are so unfortunate as to have established the habit of tight lacing, and even to those who use the article more discreetly I would remark that vigorous health can only be obtained by rejecting it altogether during the early part of the day, while employing active exercise. To children while growing the use of the corset is exceedingly fatal, and an indulgence in tight lacing is madness in those who wish to advance in their scholastic studies with rapidity.

617. You have been informed, in one of the earliest chapters, that even in man the skin is capable of carrying on a certain amount of respiration, and if this be checked by carelessness, the lungs are made to undergo too much exertion, and must be thereby rendered more liable to disease. After this remark it is needless to impress you more fully with the great importance of cleanliness as a means of promoting health.

CHAPTER XIV.

REMARKS ON DIGESTION AND THE CIRCULATION.

618. It seems proper here to offer a few remarks connected with digestion and the circulation, which furnish but so many illustrations of principles already laid down in this little volume.

619. The first preparation of food for admission into the frame consists in its proper mastication. The presence of the food in the mouth, and the muscular efforts exerted in chewing stimulate the salivary glands situated about the mouth, and induce them to pour into that cavity an increased quantity of their peculiar secretions. In order that the stomach should act properly upon the solid portions of food, it is necessary that the latter should be divided into very small portions, and each portion requires a coating of saliva, not only to facilitate its passage down the œsophagus, but to assist in dissolving it. The solvent powers of the saliva are truly astonishing, for it is capable of slowly eroding almost every substance, except, perhaps, glass, platina and the enamels, such as those of which artificial teeth are constructed. Even gold, unless very pure, does not entirely resist its action.

620. You may judge, then, how trying to the vital power of the stomach must be the disgusting habit of bolting provisions in the manner for which our countrymen are so unenviably distinguished, and you may also infer some of the ill consequences of the use of tobacco, which exhausts the saliva, and, by constantly stimulating the glands to undue activity, vitiates its quality.

621. As an additional proof of the importance of mastication, it may be mentioned that large portions of solid matter taken into the stomach cannot be moved with sufficient ease from one part of the cavity to an-

other, in order to bring all portions of the food successively under the full influence of the coats of the organ by which the function of digestion is carried on. When fresh milk is taken rapidly and in large quantities, it coagulates in one mass, and cannot be broken down for a long time by the stomach, and it is therefore extremely difficult of digestion. But when formed into curd and then masticated, or when boiled for a few moments with a very little flour or bread, which prevents it from coagulating, it becomes an agreeable article of diet even to those who dare not employ it in its ordinary state. Under the pressure of starvation, on wrecks or in boats at sea, when the mariner is driven, through dire necessity, to prey upon the bodies of his fellow-sufferers, men have been known to slake their horrible thirst with large draughts of human blood. This forms a very firm coagulum, which would be regularly digested if broken in pieces, but is perfectly indigestible in the mass; and the death of the individual almost always follows his rashness.

622. Arrived in the stomach, the food is subjected to the action of other solvents besides the saliva. A peculiar secretion from the coats of the organ, known by the name of the gastric juice, and thrown out whenever food enters, is the principal agent in this business. It has the power of preventing the food from being decomposed by the heat of the stomach, as it would be in the open air, under the same temperature. But this power is lost wholly, or in part, not only in many diseases, but in cases of general debility, weakness of the abdominal muscles (615), or loss of tone in the muscular fibres of the stomach. This accounts for the rejection of food so often occurring in dyspepsia, and shows the cruelty frequently exercised towards the young and feeble by silly nurses and robust guardians, when they press their charge to eat though they have no appetite, or to subsist upon food that proves disgusting from peculiarity of taste. These things are natural indications in most instances of the condition of the health, and cannot be entirely disregarded with impunity. I have enlarged

upon this subject in another volume, which may, some day, fall into your hands.*

623. The stomach acts first upon those parts of the food which lie next its walls, keeping the undigested mass in the centre. As layer after layer of chyme is formed, it is carried to the pylorus by the vermicular motion produced by the muscular fibres of the stomach, and passes through that orifice into the duodenum, until the process of digestion is complete.

624. The first steps in digestion seem to require the greatest exercise of vital power, and while they are accomplished, the nervous energy of the organ, as well as the quantity of blood contained in it are much increased. Hence eating is generally followed, first by a chill, the result of the calling of the blood from the surface, and then by a fever, owing to the rapid action of the heart in quickening the circulation (274). All exertion, whether of mind or body, should be avoided at this time, that the powers of life may not be called off in other directions to the disturbance of digestion (276). At least an hour of rest should be allowed after our principal meal, if it be possible. Those of you who endeavour to study a difficult subject immediately after dinner will understand what I mean. The half dreamy luxury of the siesta at this time promotes health in persons who have reached middle life; but, except in debilitated individuals, the vital functions are too active in the young to require such absolute repose, and that is idleness in them which may be almost a necessity with their parents.

625. Water seems to be taken up or absorbed very rapidly *by the veins* of the stomach, and enters the circulation almost immediately; but the dissolved solid portions of food are not thus absorbed, and must pass into the small intestines, to be there taken up by the lacteals.

626. Having passed into the duodenum, of which the

* *Popular Medicine, or Family Adviser.* Philadelphia, 1838. Published by Carey, Lea and Blanchard.

functions seem to bear some analogy to a second stomach, the more nutritive parts of the chyme are converted into chyle by the action of the bile and the pancreatic juice. It is then prepared to enter the circulation, and the whole mass driven forwards into the other portions of the small intestines by the successive contractions of the circular muscular fibres of the canal behind it, and their relaxation in front. This peculiar motion of the intestines is called *the peristaltic motion*.

627. When certain poisons or very irritating substances are received into the stomach, or secreted there in consequence of disease, they often produce vomiting. In this effort the pylorus is closed as by a spasm; the vermicular motion of the fibres of the stomach is reversed, and its contents urged towards the cardiac extremity. An involuntary violent and sudden contraction of the stomach, and of the abdominal muscles also, then ejects the contents through the œsophagus. If this effort be frequently repeated, it is found that the peristaltic motion of the duodenum is reversed, and its contents are thus forced upward through the pylorus into the stomach. But the agitation and strong pressure of the abdominal muscles in vomiting empties the gall-bladder into the duodenum. The bile then commonly enters the stomach in consequence of the reversed action of the fibres. This fluid, which, as you have been informed, is the natural purgative, has no business in the stomach, and when admitted there, it acts as a powerful emetic. This keeps up the vomiting, rendering it more and more distressing, until the gall-bladder is entirely emptied. Now, although emetics are useful remedies in certain cases, you see at once the folly of the popular notion that the discharge of bile produced by them, is a proof that the patient is "*bilious*," and the remedy, therefore, proper. Emetics are much too frequently and too lightly used without advice. If the discharge of bile be a proof of biliousness, the medicine will always produce the disease if taken by a healthy man.

628. It is unnecessary for me to trace out the course of the food through the small intestine into the great intestine, whence the valve already described (596) prevents its

return. What most interests us is the nourishment in the form of chyle, which, being taken up by the lacteals, soon enters the blood-vessels, becomes converted into blood in passing through the lungs, and goes to supply new particles to all parts of the frame, as well as materials for the various secretions.

629. Whatever has a tendency safely to accelerate the circulation, promotes the vigour of all parts; and I shall have occasion presently to describe some of the effects of exercise in effecting this purpose: but it is necessary to premise a few words upon the structure of the blood-vessels.

630. You have been informed (261), that the heart and arteries are lined internally, throughout their entire extent, by a thin membrane, which is doubled upon itself in certain places so as to form regular valves; as, for instance, between the auricles and ventricles of the heart (261), and at the origin of the great arteries (262). This membrane bears much resemblance to those called serous; such as the peritoneum and the pleura. It also lines the capillaries, and, passing into the veins, furnishes them with an internal coat, and forms all the valves already mentioned as peculiar to those vessels (see fig. 29, page 97). Though strengthened by other coats in most places, this membrane is all that is absolutely essential to the structure of a blood-vessel. In the solid parts of the bone, where no external protection to a vessel is necessary, it is said that the veins are composed exclusively of this internal coat, which indeed is little else than one great cell of cellular tissue, with innumerable branches connected together in a complete net-work.

631. But so delicate a membrane would be perpetually liable to being torn or burst, if it were not strengthened by some firmer protection. In the bones, the firm earthy matter supplies this support, but every where else the blood-vessels are provided with a thick, firm, external coat, composed of fibrous cellular tissue, which is so strong in the arteries that these vessels do not even collapse when empty.

632. These two coats are sufficient for the veins, which are almost passive canals for the conveyance of the blood towards the heart; but the arteries and capillaries take a very active part in directing the route and determining the rapidity of the circulation. For this purpose they are provided with a third coat, placed between the other two, and composed of very contractile fibres, resembling in function the muscular fibres of the alimentary canal (368). When cold is applied to a part, these fibres are stimulated to contract: less blood reaches it, and it becomes benumbed and pale, in consequence of the diminished supply of blood to the nerves (311). When an injury happens to a part, these fibres relax themselves, more blood flows through the vessels, and the sensibility of the part is heightened. Thus you see the weakness of one part becomes an immediate source of strength to another, and the reverse. This principle applies to the history of all stimulants that are local in their action.

633. It is by means of the tonicity of the *fibrous coat of the arteries*, then, that the blood-vessels adapt themselves to the ever-varying amount of their contents, and furnish to each part of the body the amount of blood that its particular condition at the time requires. It is by this power that they raise the blush of emotion on the cheek, send additional supplies to a wounded part to enable it to heal, and propel their fluid to the stomach after dinner for the purpose of digestion. If we draw blood so rapidly as to empty the arteries faster than their fibrous coat can contract, the patient faints. The heart continues to palpitate, slowly, and by habit, but it cannot urge the fluid forward through an empty hose, nor can the veins continue to refill it, while the arteries are unable to force the fresh supplies of blood into those canals. The patient would never recover, were it not that the arteries continue to contract even during his insensibility, and at length they press upon their remaining contents with sufficient force to allow the heart to renew the circulation. Fresh blood then reaches the brain again, and the faculties revive. So great and so

durable is the contractility of the fibrous coat, that in the act of death they completely obliterate the canals which they surround, and although they relax themselves again at the last moment of departing life, they are found completely empty in the dead body; all their blood being expelled from them into the veins.

634. The veins are far more numerous than the arteries. In most parts of the body, each principal arterial branch is usually attended by two venous branches. In the extremities, and the walls of the great cavities, many of the veins pursue their course among the muscles at a distance from the surface, while another set are found almost immediately beneath the skin. When we use long continued and powerful exertion, the muscles compress the deeper seated veins, and embarrass the circulation in that direction; but the superficial veins then become distended, and thus supply the deficiency.

635. Moderate and varied exercise, on the contrary, promotes the flow of blood through the deep-seated veins, by a most beautiful mechanical process. As the muscles, in such exercise, are alternately contracted and relaxed, the veins which they cover are alternately emptied by their pressure, and again suffered to become filled. Now while they are momentarily compressed, the blood cannot flow backward towards their extremities; for this motion is prevented by the valves, (184). It is therefore urged suddenly forward in the direction of the heart, whence other valves prevent its return. The empty vessels then offer no opposition to the entrance of fresh blood from their branches, for they are not allowed time to contract and diminish their size, and they become filled instantly when the muscle is relaxed.

636. The constant repetition of the process just described produces a very rapid and constant current towards the heart. The heart being filled more readily than usual by this means, beats much more frequently in a given time, and hastens the circulation throughout the frame. As a necessary consequence of this state of things, more blood flows through the lungs, and in order

to purify it, the breathing is rendered very rapid. Every part of the frame thus receives more nourishment, the colour of the blood is heightened, and life and vigour are increased in every organ. Such, you are aware, are the common results of active exercise.

637. This increased energy of the circulation may prove dangerous when any particular organ is already in a state of too great activity, for it may then be stimulated beyond its capacity of endurance, and disease may follow. For the same reason we enjoin absolute rest in cases of severe inflammation; for, in such cases, it is our desire to lessen the excessive vital energy in the part by restraining the force of the circulation. Much mischief has been done by ill-regulated exercise, employed without due reference to the condition of internal parts.

638. It often happens that persons in a state of extreme debility require the benefits of exercise when they are unable to endure the fatigue. It is easy to produce similar changes in the circulation, even while the patient lies in bed, by acting on the superficial veins. Frictions on the surface evidently bring about the same result with exercise, and no doubt much of the great benefit resulting from their application in convalescence from disease is due to this cause. The irritation of the skin which they occasion is also beneficial, by invigorating that important membrane; but the use of the flesh-brush or coarse towel is often too severe to be borne if long continued, and the effects of rubbing with the palm of the hand, or other very soft substances, have been much neglected by writers on the art of preserving health.

639. I am not at liberty to suppose that you are yet sufficiently acquainted with the principles of mechanics to comprehend fully the manner in which *passive exercises*, such as swinging, riding on horseback, sailing, and many other quiet amusements produce the same effect on the circulation with the operations mentioned in the four last paragraphs; but if you understand thoroughly the nature of *inertia*, *momentum*, the *centrifugal force*, and *elasticity*, you will be able to follow out a chain of

reasoning on this subject as successfully as I could do. You will have only to recollect that the veins are elastic tubes, furnished with frequent valves, permitting their contents to pass only in one direction, and the character of the exercise will explain the consequences.

CHAPTER XV.

ON THE FUNCTIONS OF THE NERVES AND BRAIN.

640. I MUST now request you, to re-peruse with care, the entire chapter on the nervous system, in the first part of this volume (chapter viii. page 139), in order that the contents of the present may be rendered intelligible, without the necessity of repeating definitions and references.

641. In the chapter just referred to, I have said that in the higher orders of animals, the nerves preside over the functions of the parts to which they are distributed; but this language, employed for the sake of convenience, may mislead you, as I believe it has done many philosophers, unless some further explanation is added. Even the expression that the nerves are media of communication or post-roads between one organ and another, is allegorical. We have no legitimate reason for believing that any thing actually passes along these solid cords when distant parts act upon each other through their mediation; and the doctrine of the existence of a nervous fluid, about which you will find physiologists continually talking when you read more extensively upon the subject, is a pure hypothesis—an apology for our ignorance.

642. If we take our examples from the nervous system of organic life, of which the branches do not communicate any impression to the consciousness of the individual, all we know of their functions is simply this:

the peculiar condition of the organ situated at one extremity of a nervous fibre, produces such a condition of the nerve itself, that the organ or organs with which the fibre communicates at the other extremity are changed in their condition also. An action on the nerve at its commencement, causes it to act on the parts in which it terminates. We do know that the nerve is the agent by which this mutual relation of distant parts is secured; for, if the nerve be divided, the relation ceases. This power of perceiving an impression made upon it by an influence external to itself, and consequently creating a corresponding influence upon some other part also external to itself, is the peculiar province of a nerve. It is safe, then, after this explanation, to say, in allegorical language, that the nerves receive impressions from one part and convey or communicate them to another.

643. Now every nervous fibre has its own proper function. The nerve of sight does not convey sounds, nor does a nerve of feeling convey impressions of taste. You will be somewhat startled, perhaps, to hear it asserted, that the feeling of the elbow is a different sense from that of the finger, yet I think it may be easily proved, as we shall presently see.

644. The function of a nervous fibre resides not exclusively in its extremities, but dwells in all the intermediate parts, though, perhaps, not in so great a degree. The extremities have more susceptibility than the trunk. To explain this point, it is best to take an example from the nerves of feeling; for, as they communicate directly with our consciousness, we can more readily observe the manner of their action. Nothing is more common than for a patient who has had a limb amputated to complain for many days of pains in the part that has been removed or destroyed. "Doctor," he will say, "I have a severe cramp in my toes to-day," forgetting at the moment that those toes are beneath the soil or preserved in an anatomical museum! Now the meaning of such complaints is simply this: an irritation takes place on the stumps of some of the fibres of a particular nerve, at the place where the limb has been amputated.

This may result from inflammation in the part, from the pressure of the dressings, or from the dragging back of the divided muscles as their tonic contraction renders them shorter. Such causes lead to sensations in the mind precisely similar to those which would have followed analogous injuries inflicted upon the extremities of the same fibres, had the limb not been lost; and the mind, receiving the same impression from the nerve that it would have received had the toes been injured, naturally refers that impression to the spot to which the nerve was designed to pass. You see, then, that it is the function of the whole nervous fibre of feeling belonging to the point of the elbow to convey to the mind the sensation of feeling at the elbow; and so likewise, the nerve of feeling of the finger conveys only the sensations proper to the finger,—which distinct functions they continue to perform for a certain time, even if elbow and finger have both lost their existence. That they soon lose this power after amputation, is most true; but this results from the general physiological law, that parts which are rendered useless, soon lose or change their functions for want of appropriate exercise. Some of the evidences of a similar character, presented during disease, are very curious, and tend to show the folly or wickedness of those who undertake to tamper with human health, without a deep knowledge of anatomy and the principles of physiology. In that dreadful complaint, called “hip-joint disease,” one of the first symptoms is a pain in the knee, where there is absolutely no real ailment: and had I time and space, it would be easy to quote a hundred similar instances.

645. As it is the function of a nerve to communicate the influence of external things (among which things, external with relation to themselves, we may rank the organ in which they terminate) to certain organs of the living body, in order to influence the actions of those organs, we might reasonably suspect that the nerves may communicate impressions one to another, as they do to the muscles and other parts. That this is the fact, is shown by the history of the ganglions and plexus, as

given in chapter viii. Hence results the endless complexity coupled with the beautiful conformity of motion observed throughout the animal frame.

646. The only nerves that communicate impressions directly *to the mind*, or receive impressions *from that source*, are the nerves of sensation and those of voluntary motion. The former are usually considered as including only the nerves of what are commonly called the five senses, — sight, hearing, taste, smell, and tact, touch, or feeling. The nerves of touch or feeling, for the most part, appear to originate from the spinal marrow, like those of voluntary motion; but those of the other senses, with the exception of smell, are seemingly derived from the brain near the spot where the spinal marrow, somewhat changed in structure and called the *medulla oblongata*, terminates in that portion of the nervous system. The portion of the nervous system which presides over the sense of smell is very peculiar in structure, but the details are foreign to our present purpose.

647. When we come to examine the question strictly, we find that the nerves of the five senses have really, of themselves, no sensation whatever: for if you divide a nerve of feeling, the part of it which is cut off from the brain becomes instantly incapable of feeling. You may make this division as near the origin as you please, yet the result will be the same. In the same manner, you may prove that the eye does not see, nor the ear hear; for both these organs may be perfect in organization, yet they are rendered perfectly useless if the *optic nerve* of the former, or the *auditory nerve* of the latter be cut off at its origin by disease or accident. It is customary with many physiologists, then, to say that these nerves report or convey all their impressions to the brain, and the inference is apparently plain that it is the brain that sees, hears, and feels. Let us examine what is the brain, and what are its functions.

648. The brain, of which something has been said in chapter viii. (284, 285, 286), is a great mass of nervous matter filling the entire cavity of the cranium,

(399) and enveloped in several membranes. When we remove the top of the cranium, in a dead animal, we first encounter a thick, strong, fibrous membrane, furnished with many blood-vessels, and acting as an internal periosteum to the cranial bones. This is the dura mater (421). It extends throughout the spinal canal, thus enclosing that cavity and the interior of the cranium as one undivided chamber.

649. The dura mater presents us with a curious process called the *falx* or *sickle*, the blade of which instrument it strongly resembles. This process partially divides the cavity of the cranium into two chambers. It consists simply of a curtain formed by a doubling of the membrane, and is suspended from the middle line of the arch of the cranium. It is very narrow at its commencement from the ethmoid bone (419), just within the root of the nose, but becomes broader and broader as it sweeps upward, along the middle of the frontal bone (400), backward, along the suture joining the two parietal bones together (406), and downwards along the upper limb of the cross of the occipital bone (410, 411, 412), to the centre of that cross, where it is quite wide like the heel of the blade of the sickle. Here it joins with, or is continued into two similarly constructed curtains, which lie horizontally and extend along the two lateral limbs of the occipital cross to the temporal bone, and are even attached to the angular edge of the petrous portion of the bone (414). These horizontal curtains, taken collectively, are called *the tentorium*.

650. The tentorium is the membranous floor on which rests the posterior part of the cerebrum or greater brain, and separates it from the cerebellum or lesser brain (412).

651. A narrow curtain of the same character extends from the lower surface of the tentorium, along the lower limb of the occipital cross, to the great occipital foramen (409). It is called *the lesser falx*.

652. Thus you see that the arch of the cranium is divided into four great compartments, by the partial partitions formed by the falces and the tentorium. The two upper compartments are occupied by the cerebrum,

separated into two similar halves, called the *right and left hemispheres*, by the greater falx. The two lower compartments are occupied by the cerebellum, similarly separated by the lesser falx.

653. When the dura mater is cut away, we come next upon the serous membrane of the head, called the *arachnoid* or *spider-web membrane*, from its extreme delicacy. It is transparent, and so thin that anatomists are often puzzled to separate it from the parts beneath. It is spread smoothly over the general surface of the hemispheres, enters and lines several cavities within the brain, and follows the spinal marrow to its termination.

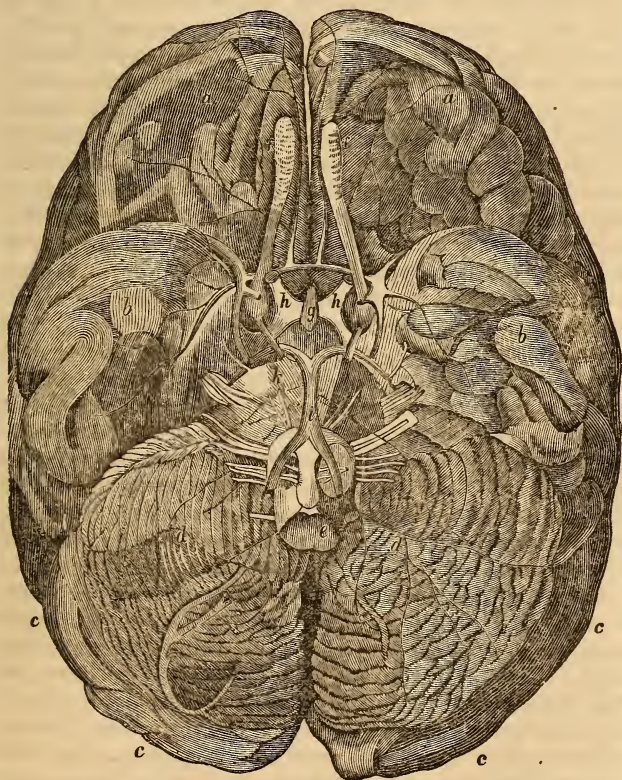
654. Through this membrane, and the one immediately beneath it, we see the surface of the brain, which is every where varied in surface, so that it looks as if composed of a long tube, like the intestines, folded and winding upon itself, in order to occupy as little space as possible. These turnings of the surface are called the *convolutions*. They are more complicated and numerous in the more lofty animals and at mature age, than in the humbler animals and in the young.

655. Beneath the arachnoid membrane we have the *pia mater*, or proper membrane of the brain, which embraces the cerebral substance very closely, following all the irregularities of the surface, and dipping into every depression between the convolutions. The *pia mater* is full of large blood vessels, and supplies the substance of the brain with all its capillaries. It then descends along the spinal canal, performing the same office for the spinal marrow, and furnishing the proper covering or neurilema (289) to every nerve as it quits the canal. In one sense, then, it may be regarded as the natural envelope of the whole nervous system.

656. The *pia mater* being removed, we come to the naked brain. In figure 57, you are presented with a view of the lower surface of this part of the nervous system, with many important nerves originating from it. You observe that each hemisphere of the cerebrum is divided into three lobes. The anterior lobe, *a*, lies over the eyes, in that depression of the base of the cra

nium (399), marked *g*, fig. 42, at page 183. The middle lobe, *b*, occupies the depression marked *h*, in the figure to which I have just referred. The posterior lobe, *c, c*, lies on the upper surface of the tentorium, and fills that portion of the cranium which lies above the centre of the occipital cross (*c*, fig. 42). The superior surface of the cerebrum does not present this lobulated appearance, but conforms to the regular arch of the skull.

Fig 57.



657. At *d, d*, you see the two hemispheres of the cerebellum, which, lying under the tentorium, fill up those deep depressions, one of which is marked *i*, fig. 42, that lie below the horizontal limbs of the occipital cross. The convolutions of the cerebellum are much smaller and proportionally more numerous than those of the cerebrum, as you will perceive on reference to the figure.

658. The letter *e*, designates the extremity of the spinal marrow, cut off just where it enters the head; *f* is a very peculiar extension of cerebral matter lying on the cribriform plate of the ethmoid bone, and usually termed the olfactory nerve; *h* represents the optic nerves or nerves of sight, dividing at the place where they enter the orbit of the eye; *i* is one of the large blood-vessels of the brain; and *k* represents a rounded mass chiefly of medullary matter, placed at the junction of the cerebrum with the cerebellum and the spinal marrow. The white fibres represented as springing out from near the middle line of the base of the brain, represent the origin of as many nerves which pass out of the cranium, and are distributed to various parts, but chiefly to the head, face, and the organs of the special senses.

659. After this hasty glance at the outside of the brain, let us peep into the interior. The nature of the cortical or cineritious, and the medullary matter have been explained already (283, 284), and you will remember that the latter is composed of regular rows of globules, precisely like all other nervous fibres, except that they are not provided with a neurilema. Each of them constitutes then, a nervous fibre in the condition in which it is found within the substance of a ganglion.

660. But the only change in the situation of nervous fibre, while divested of its neurilema and passing through a ganglion, appears to consist in its being brought more nearly within the influence of the surrounding fibres, so that the diseases and accidents of the one may produce morbid effects or healthy impressions on the other. There exists no fact which will warrant us in supposing that the peculiar function of a nervous fibre is ever essen-

tially changed in character, even within a ganglion, unless it come into contact with cineritious matter, and derive from it an addition to its substance.

661. All the fibres of the brain originate or terminate in cineritious matter, and those which come from or pass to the different parts of the body, external to the cavity of the cranium, appear to have their commencement or their ending in the cortical matter of the surface of the brain. Now every one of these fibres is a distinct organ, having its own proper function (643), and nearly, if not quite, all of them convey to the mind the impressions made upon them by external things, or receive from the mind the orders of the will; for they are nerves of animal life.

662. Some have supposed that the communications between these fibres and the mind, take place in the cortical matter where they terminate. But this is impossible; for every surgeon knows that portions of the surface of the brain are often lost by persons wounded in battle or otherwise, and yet, in many of the cases, no part of the body may be deprived of either sensation or voluntary motion. The integrity of the whole brain, then, is not necessary to the exercise of consciousness and will.

663. Consequently, *these powers are not functions of the whole brain.*

664. It has been found that if you slice away gently, one layer of brain after another, in a living animal, you may remove a very large portion of it without entirely destroying the evidences of consciousness and will. There is every reason to believe, from a vast number of careful experiments, that, but for the general disturbance of the nervous system, (and consequently, of the functions on which the preservation of life depends,) together with the extreme complexity of the organization, which prevents us from removing exactly what we wish without injury to *other parts*, we might continue to take away all that is *essential* to the brain, and as long as a trace remained, some signs of consciousness and will might still appear. One reason why we fail in such

an undertaking, independently of loss of blood and other causes which destroy the animal before the experiment can be completed, is, that when we approach the base of the brain, we inevitably wound the fibres of the spinal marrow as they enter the brain, and thus cut off the route by which the external senses convey impressions to the mind: the whole body is palsied, breathing ceases, and the animal dies.

665. But enough has been ascertained in this way, to prove to any dispassionate examiner, that *consciousness and will are not functions of any part of the brain in particular.*

666. Now it has been already shown that these powers of mind are not functions of any other part of *the nervous system*, and no one pretends that they are functions of any other part of *the frame*. If this train of reasoning be correct, it follows inevitably that *consciousness and will are not functions of the animal organization.*

667. By keeping this in remembrance, you will escape a thousand errors, into which many dangerous, though highly important and useful physiological doctrines of modern times might otherwise lead you. It is not a nerve,—it is not the brain that is conscious,—but the mind! It is not the nerve or the brain that wills,—but the mind! There are those who will tell you that the will is the result of the combined action and mutual influence of *all the organs*, but you are now provided with a sound physical argument against the doctrines of these materialists.

668. But if the brain be diseased or wounded, our will and consciousness are always weakened or led astray. Why is this? Because the brain is interested in conveying to the mind those impressions which arouse the consciousness, and in carrying from it the orders issued to the organs. If the diseased or weakened nerve convey feeble or erroneous impressions, the orders consequent upon them will be feeble or erroneous. Through a disease of the nerves of voluntary motion, we may even *will* one thing and *do* another. Hence, in this state

of existence, our mental operations are modified by the perfection or imperfection of our organization, and though we cannot be justly held accountable for the false impressions conveyed by our senses, *we are accountable* when our will is permitted to run counter to the tenor of those impressions, or when our voluntary acts have led to the neglect or injury of the organization—the machinery—placed under our control by Providence.

669. There are some, especially among the older physiologists, who have formed and promulgated the idea that there is some central spot in the brain, where all the messages conveyed by the nerves are ultimately reported, and whence all the orders of the will are issued—the peculiar seat of the mind. Descartes placed it in the pineal gland, a small body in the interior of the brain *which secretes a few grains of a substance resembling sand!* His wild hypothesis is just as dependable as any other urged on this subject. Were there any such centre, it would be at some point where all the nervous fibres meet, but no such spot exists.

670. The cineritious matter of the brain is not confined to its surface, but is found in several places curiously collected into masses intermingled with fibres. Now, if you turn to the description of the ganglia (295), you will find that this arrangement is essentially the same with that observed in those organs. Indeed, the general surface of the brain is constructed on the plan of a large, flattened, and convoluted ganglion; and there is no reason to employ a variety of terms in speaking of similar things.

671. The brain, then, may be regarded as a great collection of large ganglia collected together into one mass, and connected by numerous fibres unprotected by neurilema. Soft and pulpy as these fibres are, we can sometimes distinguish bundles of them passing from one mass of cineritious matter to another, throughout the substance of the brain; thus forming regular naked nerves pursuing a different course from the fibres constituting the great bulk of the medullary matter in which

they are embedded. Each of these bundles must possess its own peculiar class of functions, for each is a distinct part of the nervous system. Such nerves are generally termed *commissures*, and they are supposed to form connexions between corresponding portions of the two hemispheres in order to cause them to act in concert. Many modern discoveries which you are not prepared to understand are calculated to add probability to this conclusion.

672. As the health and perfection of the brain — the principal instrument of the mind — is necessary to the full display of what we commonly call the mental faculties, you would naturally suspect that the more complex the structure of the brain of an animal, the greater will be the vigour of its mental faculties. Now, so far as human research has yet penetrated with accuracy, such is the general result.

673. When we cast a broad glance over the whole chain of animated nature, we observe that the nerves of organic life seem to make their appearance before the spinal marrow, and that this organ is completed before the brain presents more than a mere rude button on its summit. Even this button appears to compose chiefly the rudiment of the cerebellum; and this lesser brain reaches a high degree of developement and complexity of structure, even while the cerebrum continues a simple smooth mass of nervous matter, with scarcely a trace of the convolutions to be seen. As we advance towards the higher classes of animals, the cerebrum becomes more and more involved in structure, and the closest of observers are of opinion that this progress of developement answers very nearly to the order in which the apparent intelligence of the animal increases.

674. In ascending the series of vertebrate animals, from the simpler tribes to man, it appears that the cerebellum is first brought to perfection; that the posterior lobes and the base of the cerebrum are next in progress; that the upper portions of the middle and anterior lobes are superadded in the more lofty creatures (656)

but do not reach their ultimate condition until we arrive at man.

675. The progress of the brain from infancy to manhood is well known to be in most respects similar to this. The base of the brain and the posterior lobes are first developed, the middle lobes claim the ascendancy in youth, and the anterior lobes hardly acquire their full relative size and firmness before the age of thirty years.

676. The observations mentioned in the four last paragraphs have induced a very general and natural belief among physiologists, that the organization of these several portions of the brain has something to do with the display of the faculties which distinguish the various classes of animals; but, in the hands of a modern sect of philosophers—the *phrenologists*—this opinion has been carried out in detail, as I shall presently have occasion to state.

677. Infancy is governed, like the animals, mainly by the instinctive feelings; for it is yet asleep to its responsibilities, and has not acquired more than the rudiments of its rational faculties. The base of the brain being then much farther developed than the upper part, is it not reasonable to conclude that the nervous fibres which convey to the mind the impressions which awaken the instinctive emotions are located in that part of the brain?

678. Childhood and youth are governed mainly by the moral sentiments and loftier affections; and in those states of being, the upper-portions of the middle lobes gradually approach their highest perfection. *If, then, the mind requires material instruments to call these faculties into play—if the proper organization of the brain be necessary for their display*—are we not warranted in locating their proper tools in the middle lobes of the cerebrum?

679. Manhood is distinguished by the perfection of the reasoning faculties, and it is that portion of the brain which fills the cavity of the superior part of the forehead—the upper portion of the anterior lobes—that then, for the first time, acquires its full dimensions and com-

pletes the structure of the nervous system. *If there be any part of the brain necessary to the exercise of the reasoning faculties*, where are we so likely to find it as in the anterior lobes?

680. If you acknowledge the force of these remarks, you grant all the fundamental principles of that highest branch of physiology, called *phrenology*, which is simply *the science that treats of the functions of the brain*. But phrenology, like all novel subjects of human research, has been loaded with empirical pretension on the one hand, and ignorant attack upon the other, till its rational cultivators can scarcely recognise its features as drawn either by its professed friends or foes in general society. I do not propose to initiate you into the details of its doctrines, much less into the practical application of its principles to the judgment of character; for if the truth of the details be acknowledged, their application is so difficult, and the sources of error so numerous, and as yet so slenderly investigated even by its avowed advocates, as altogether to unfit it to form part of an elementary education. He is a bold man who, after long years of patient study, based upon a thorough professional education, ventures to express decided opinions upon character on phrenological grounds, or to undertake the task of opposing the broad doctrines of the science. But, as it is desirable that every well educated youth should have some slight conception of the nature of a subject that has attracted so much attention of late years, if it be only to guard him against the ridiculous mistakes from which even avowed disciples are not *always* exempt, I will venture a page or two of illustration. My remarks will be drawn rather from acknowledged anatomical authorities and the book of nature, than from the statements of partisans.

681. The spinal marrow—a nervous centre, or rather centres, belonging to the system of nerves of animal life—occupies the cervical, dorsal, and a small portion of the lumbar divisions of the spinal canal (463), the remainder, containing chiefly the commencements of

the very large nerves of feeling and voluntary motion, designed to supply the lower portions of the frame.

682. If you divide the spinal marrow horizontally, you find it to consist of four principal columns of longitudinal, naked nervous fibres, and in the centre you perceive a long mass of cineritious matter, which, in section, presents the appearance of a Maltese cross. One portion of this cross seems to appertain to each of the columns of longitudinal fibres.

683. The four columns of longitudinal fibres continue their course upwards, until they come into the cervical region of the spine; and these portions of the nervous system evidently belong chiefly to the apparatus of sensation and voluntary motion; though, through the sympathetic nerve, they have many connexions with the apparatus of organic life.

684. In the cervical region of the spine, two other columns of longitudinal fibres are superadded, which are known chiefly to preside over the motions connected with respiration.

685. It is not unphilosophical, then, to regard the spinal marrow as four very long ganglions, with two much shorter ones associated with them at the upper extremity.

686. These six columns of longitudinal fibres enter the head together through the great occipital foramen, where they enlarge themselves into a kind of bulb, which I have heretofore included in the general description of the spinal marrow, but which deservedly bears a distinct name. It is called the *medulla oblongata*, and it lies on the cuneiform or wedge-shaped process of the occipital bone. Fig. 57, *e*.

687. At this point the fibres of the several columns intercross each other from opposite sides, and become intermingled with portions of cineritious matter in a manner that I am not permitted to suppose you prepared to comprehend, for I am not addressing you as anatomists.

688. Passing under a thick mass of medullary matter (fig. 57, *k*,) which is one of the commissures of the

brain (671), the fibres are again divided into four great columns, one of which passes into each hemisphere of the cerebrum, and one into each hemisphere of the cerebellum.

689. From this point the fibres of the several columns spread themselves out so as to run towards all parts of the circumference of the brain, to terminate in the cineritious matter of the convolutions.

690. But the mass of the brain vastly exceeds that of the medulla oblongata, and most of its bulk is made up of medullary matter, and consequently, of nervous fibres. A very small proportion of these fibres are interested in forming the commissures, which run transversely, and by far the larger portion correspond in their direction with those diverging from the four columns mentioned in the two last paragraphs. Hence it follows that, as the fibres of the columns separate, on their way to the convolutions (689), a great multitude of other fibres, proper to the brain itself, are added to the number, and we have no reason to believe that these fibres, which never leave the brain, have any immediate relation with the external senses. Even the fibres of the spinal marrow, after they actually enter the brain, appear to lose their power of awakening consciousness when irritated; for the brain itself is entirely divested of feeling: you may cut it or crush it piecemeal, without making pressure on the spinal marrow, and the patient will utter no complaint.

691. It is a curious circumstance, that all the fibres running towards the convolutions are so arranged that those passing to opposite sides of the same convolution do not intermingle, but a line of demarcation exists between them; and by taking off a portion of the upper surface of the brain, you may spread out the convolutions, so as to make the surface flat, without tearing a fibre. When water collects very slowly in certain cavities existing in the brain, provided the dropsy occurs in infancy, before the bones of the head are firmly united, the greater part of the upper surface may be distended, so as to resemble a bladder formed of

cineritious matter externally, and medullary matter within. Yet such is the power of the vital functions in adapting the frame to accidental circumstances, that a child so affected may not lose its intellect. The fibres are lengthened, so as to accommodate themselves to their new position. Instances have been known, in which the bones of the cranium have become perfectly ossified over such alterations of the brain, and the patients have reached a mature age, or even middle life, with a head of twice or thrice the natural size; but such persons generally become idiots. I saw a case of the kind in the almshouse of Newport, Rhode Island, in 1838: he is still living.

692. Now, as every nervous fibre is a distinct organ, having its own appropriate function (290), it is evident that there are many nervous organs within the brain whose functions must be different from the functions of those which are found externally to the cranium. The founders of phrenology have essayed the discovery of these functions, which is as legitimate a subject of research as is any thing connected with the nervous system. But as consciousness and will are not functions of the nervous system, it would be in vain to attribute any form of these faculties to the nerves of the brain; and it is probably by the neglect of this fact that the founders of phrenology have involved themselves with so many of the moralists of the day, and have drawn down upon themselves the hostility of some whose talents would have been better employed in correcting the error than in combating those doctrines of the science which are susceptible of proof.

693. Phrenology is a physiological, and not a metaphysical science. But some of its advocates have taught the doctrine, that those organs of the brain which they conceive to be the organs of the moral sentiments are *motor powers*, or that *all our conduct resulting from the promptings of these sentiments*, is the inevitable consequence of peculiarity of organization; thus depriving the individual of all control, and, of course, of all responsibility; a doctrine that sinks us at once and inevitably

into the darkness of materialism and fatalism, and one which is utterly at war with the real history of the nervous system. The nerves, as we have seen, are mere media of communication between one external thing and another; and to say that one medium of communication communicates with another, is reasoning in a circle: it is saying that one post-office communicates with another. There must be a messenger to transmit the message and an officer to receive it; where the nerves of organic life are alone concerned, the message may be sent by the stomach and received by the heart, but where consciousness is interested, there must be some independent being to whom the intimation is conveyed; for experiment proves that a nerve of feeling cannot be conscious of feeling (647), neither is any nerve of the brain, *and it is not even contended that any other organ can be the seat of consciousness. But that which is conscious, also wills*, and coupled with its will comes free agency and *accountability*;—modified, it may be, but not destroyed, by the nature of the evidence furnished by the senses. The doctrine I have been combating belongs not legitimately to the science, but has been unnecessarily engrafted upon it by some of its advocates.

694. What, then, are the functions of the nerves of the brain? Let us examine. The brain is evidently a part of the system of nerves of animal life. We must therefore seek for nervous functions of animal life not otherwise provided with proper instruments. But the nervous functions of animal life are those of the senses, and those which lead to the performance of voluntary motion. Now we know that there are no organs of voluntary motion within the cranium, and we can trace the nerves that govern the operations of all those external to the cranium. These are already provided with their proper nerves; and as the same reasoning already employed in relation to consciousness and will, applies with equal force to all the other mental faculties, there remain no known functions to be investigated except those of the senses.

695. What are the senses? They are the functions of those organs which arouse to the mind the knowledge of the existence and relations of external things.

696. Are there any senses necessary to the knowledge of the relations of external things besides sight, hearing, taste, smell, and tact or feeling? And if so, what part of the frame performs these functions?

697. Nothing is better known than that there are many individuals who have most perfect organs of vision, so far as we are able to ascertain—persons who see objects with the utmost distinctness, yet have no power to discriminate between one colour and another. Is it not probable, then, that the discrimination of colour depends upon a different sense from that of mere vision? If so, we can seek for its organs no where but in the brain, for every external nerve of sense is already appropriated.

698. One child has more natural affection for its parents than another, and some are exceedingly deficient in it. What is a parent? It is an external thing,—an object for the observation of the senses of the child. It has relations with the child which are also objects of the senses. The object is one which resembles very closely thousands of other individuals of the same species bearing a close resemblance to it. Yet the attachment is so very strong that the child will often cling to the parent in face of neglect and cruelty, while it will turn from the greatest kindness in a stranger. What informs the mind of the child of the relations in which it stands to this parent? We frequently speak of it as a keen *sense* or *feeling* of affection. If it be a sense, it must have its appropriate nerves, and these nerves can exist only in the brain; for it is totally different from every one of the external senses.

699. One man has so keen a perception of the ludicrous, that nothing that is humorous in the relation of external things can escape him. He will laugh by the hour at the accidental resemblance between the countenances of an old horse and the man who is driving him, while another, with an equally vigorous mind, will

gaze at him with astonishment, and read him a homily on his folly. This evidently depends upon a peculiar sense; and its organs must be sought in the brain.

700. When one event follows another on all occasions, we are apt to call the first *the cause*, and the second *the effect*—but this is not always true. Day follows night, but day is not the cause of night. In our little experiment with the marbles and the balls of dough (514), the blow of the first marble is the cause of the motion of the last; and this I presume you would perceive at once, even if you had never heard a single word on the subject of elasticity; yet there are men whom no explanation would convince that it was not the result of jugglery. This perception of the relation between cause and effect appears to depend upon a sense; and its organs must likewise be contained in the brain.

701. Now the phrenologists contend that they have discovered the organs not only of these senses but of many others in the brain, by observations on the form of the head. Probably they are right in some instances and wrong in others. You can judge the questions for yourselves, when age and experience have fitted you to examine the weight of evidence which they adduce in support of their position. The object of these and the following remarks, is simply to communicate some principles that may assist you in the research, should you ever undertake it.

702. The art of estimating the developement and energy of the internal nerves of the brain by examining the external form of the head, is called *cranioscopy*, and the question of its useful application is altogether distinct from that of the truth of the science of phrenology. The latter may be correct in its fundamental principle, that different parts of the brain are the organs of different senses, and yet the former may be extremely fallacious. I shall presently notice some of the principal sources of error.

703. Before speaking of the mode pursued by the founders of phrenology in attempting to determine the functions of the nerves within the brain, it is right to

mention a few facts in relation to this subject, which you may depend upon as correct.

704. The external surface of the head agrees very nearly with that of the skull. Except on the temples, where two very large muscles of the lower jaw take their rise, the integuments of the head are very evenly spread over the surface of the bone, and an anatomist finds very little difficulty in making the proper allowances for all varieties of thickness.

705. The external form of the skull corresponds so nearly in most places with that of the brain, that the one may be judged with sufficient nicety by examining the other. The thickness of the bones varies in different individuals, but the amount of difference is so slight that there is not one case in a thousand in which it would be found to confuse our estimate very seriously. The bones also vary in thickness in different parts of the same head, but the only situation in which this difference is important as influencing our judgment, except, perhaps, in some extremely rare cases, is at the lower part of the frontal bone, where the frontal sinuses are placed, and the value of this difficulty has been stated at paragraph 402, to which you may refer.

706. The celebrated Dr. Gall, the founder of modern phrenology, commenced his observations on this subject at a very early age, while still at school, and continued them through a very long life. He was assisted and succeeded by his pupil, Dr. Spurzheim, to whom, more than to any other one man, we are indebted for our present knowledge of the anatomy of the brain. The plan of observation was this: An individual of marked peculiarity of talent, such, for instance, as great facility in acquiring languages, was examined with great care, and if any unusual development of a particular portion of the head was observed, it was noted as the probable seat of the faculty; for Gall well knew that *in any individual*, the larger a muscle, a nerve, or any other organ may be, the greater is its functional power, provided it is in a healthy condition. Every person possessed of the same peculiarity in a remarkable degree who came

within reach of these gentlemen, was then compared with the first, and with all others. If all were found to possess the same peculiarity of development, the probability of its being the seat of the faculty was considered as much increased; but if some were found wanting, an error was acknowledged, and they endeavoured to find some other development common to all the cases, while they sought, in the characters of the persons observed, for some other trait of remarkable talent which should explain the previously discovered enlargement. After years of labour, they succeeded in locating to their satisfaction a number of the organs of the internal senses, or, as they have been pleased to call them, the mental faculties. It would be difficult to number the multitude of examinations made by these gentlemen in every corner of Europe. You are probably aware that Dr. Spurzheim died in the attempt to continue the same research on this side of the Atlantic. Their more careful and philosophical disciples have enormously increased the amount of observation on this interesting subject, and similar researches have been extended by the friends and foes of the doctrine throughout the whole range of the vertebrated animals. It is now acknowledged, even by many who oppose the doctrine, that these investigations have reflected brilliant light upon metaphysics, and have furnished us with a comprehensive terminology of the human faculties.

707. The brain is nourished and developed on the same principles with all the other organs. In common with them it is actually enlarged as well as increased in functional power by exercise, and the bones of the cranium change their shape to accommodate the change, even after the individual has arrived at mature age. In advanced life it becomes smaller, like all other parts, and the skull then either contracts upon it or becomes thicker, in order to fill up the intervening space. Persons ignorant of physiology have urged it as an objection to the attempt to judge what part of the brain has been developed by measuring the form of the cranium on its upper surface, that the growth may have taken

place at the base of the brain, and that the arch of the cranium may be raised in consequence of its contents being thrust up bodily: but this objection is without foundation. It is a law of the animal economy, that when the healthy growth of any organ in a cavity requires a development of its walls, they are enlarged to accommodate the increased size of that organ, just where the accommodation is most necessary, and without displacing other important parts. Even the progress of disease often shews this beautiful arrangement still more remarkably: for most morbid anatomists have observed soft tumors upon the dura mater within the head, which, instead of pressing down upon the soft brain beneath, have risen up until they have appeared externally, the hard bone being absorbed before them to give them passage.

708. Whatever may be said or thought of the value of cranioscopy as a guide in judging of the balance of the different faculties in the head of an individual, and of the light it throws upon education in pointing out what organs of the brain are weak and require strengthening by trained exercise, there can be no doubt that the difficulties opposing the comparison of the powers of one individual with those of another are so great that its application with such a view is often as fallacious as it is invidious.

709. On the principle that the larger an organ is, the greater is its power, the phrenologists tell us that, *other things being equal*, he who has the largest brain will possess the greatest degree of mental power. But nothing can be more erroneous than this position, as it is commonly understood; for A. may have a much larger head than B., yet from a certain disproportion between the lobes of his brain, A. may be scarcely capable of making himself an available citizen, while B. may possess a very energetic character. A man who should possess enormous intellectual powers with scarcely any passions, might be less dangerous to society, but he could hardly be more useful to himself than a man with violent passions and very little intellect. But, even grant-

ing their position—in calculating *the equality of other things*, the phrenologists take little notice of any thing else than the temperament. They grant that a man with a small head and a nervous temperament may be more powerful than another whose head is large but whose temperament is lymphatic. At the close of the next chapter, which speaks of the temperaments, you will find a notice of a most important and not uncommon error upon this subject.

CHAPTER XVI.

OF TEMPERAMENT AND IDIOSYNCRASY.

710. IN another part of this volume (270, 271) it was stated that the powers of life were unequally distributed throughout the different systems of organs composing the animal frame; but each system and each organ received such an amount of the vital powers as its wants, with the energy and rapidity of its functions, require. This produces an equilibrium of action throughout the frame which is consistent with the highest health.

711. But certain moderate changes in this balance are observed to take place in different portions of the human family without being absolutely destructive of health. Circumstances of climate, education, hereditary peculiarity, or habits of living, may produce a change in the relative developement of any organ or system of organs; thus giving unusual influence to those portions of the frame in the general balance of life, without inducing positive disease. And these changes may be either general over a whole system, or local, in a single organ.

712. The circumstances in which the individual is placed may even require such changes, in order that

health may be preserved; for the organization best adapted to a cold climate is well known to be dangerous in a warm one. It is probably owing to the extent to which the balance of life is capable of modification, that man is indebted for his remarkable power of becoming accustomed to variations of climate which prove destructive to all animals, even to those of a domestic character. Though these animals share largely in the susceptibility of change, none of them, unless it may be the domestic dog, will live beyond a certain range of latitude. We cannot transfer the camel to Lapland, or the reindeer to the tropics: and you will readily perceive, in the operations of this law, and the effects of hereditary tendencies, the causes of most of the peculiarities of nations and races of men as well as individuals.

713. When an individual has all parts of his frame so *tempered* to each other as to be balanced in the manner most consistent with the health, longevity, and perfection of vital power, he is said to be of a *natural or correct temperament*—if otherwise, he has a *peculiar temperament*.

714. It is evident that the number of temperaments, general or local, observable among mankind, must be indefinite, but that the former are likely to be much less numerous than the latter. When the word temperament is used by physiologists without a prefix, reference is made to the general modifications only. (711.)

715. Numerous as are the distinctions between races and nations, we find, in all countries, a large number of persons distinguished by the characters of a very few general temperaments. The shades, the degrees, and the intermixture of these in individuals are beyond number, but in a very large proportion of mankind some traces of one or more of them may be detected.

716. These general modifications of structure are necessarily productive of peculiarities in the appearance and in all the vital operations—in the effects of food and medicines, and in the display of the mental faculties. They are well worthy of such notice as we have space

to give them. Physiologists now generally enumerate four principal temperaments: the *sanguine*, the bilious, the *lymphatic* or *phlegmatic*, and the nervous. When intermingled with each other, they are designated by the titles *sanguineo-nervous*, *bilio-nervous*, &c.

717. *The sanguine temperament*, when moderately marked, is considered as approaching most nearly to the natural condition of health. It is the result of a just balance between all parts of the vascular system, and the other systems generally. When decidedly marked, it produces a highly florid complexion, with a well-rounded outline of all parts of the frame; a moderate degree of fulness, with the divisions between the muscles well, but not strongly defined, so as to render them decidedly, though not strikingly prominent; a skin flexible, but not very yielding; and the flesh firm but compressible and elastic. The blood is highly coloured, and tinges the cheeks, lips, gums, &c. of a brilliant red: its serum and coagulable portions are equally balanced. The animal heat is pleasant, moderate, and diffuses itself readily. The perspiration is free but not excessive. The colour of the hair and eyes varies from so many accidental circumstances, that it is not a safe guide in judging of general temperaments; but, in the sanguine, it is generally light, though rarely very light, and very seldom black.

781. As you would naturally suppose, all the vital operations and the mental faculties are carried on very rapidly, and with full energy, in persons of this temperament. The nutrition of all parts is remarkably perfect: the muscles are powerful, the mind vigorous, and the feelings and passions quick.

719. When this temperament is excessive, the individual becomes peculiarly liable to inflammatory diseases, which are always sudden in their attack, generally short in their duration, and violent. They often require prompt and energetic depletion, but will rarely endure well the long continuance of debilitating treatment. The temper of such persons is also violent but evanescent. They pursue their studies and other mental

exercises by paroxysms very energetically, but soon weary of their occupations; are speculative, daring, often incautious, and accomplish great results occasionally, but rarely succeed in those pursuits that require great prudence or untiring perseverance.

720. Sometimes the venous system is more developed than the arterial, giving rise to a less general temperament, marked by a bluish or yellowish tint of those parts of the surface which in the purely sanguine, are florid. Persons of this temperament have veins unnaturally large and liable to disease in advanced life.

721. Sometimes, the veins of the abdomen belonging to the portal system (599), are, alone, thus unduly developed. When strongly marked, this is hardly consistent with continued health, and very greatly modifies the character of febrile and other diseases attacking those in which it is displayed. I mention these two last varieties merely as illustrations of partial or local temperaments.

722. *The bilious temperament* is marked by an excess of nutrition in the more solid parts of the body, and especially in the fibrous organs. By some it is considered as indicative of the still greater energy of the circulation; be this as it may, there is an obvious difference in the character of the blood in this temperament. Its coagulable portion is increased and its serum is not so abundant. The lymphatic system is less developed, and the fluids of the body bear a smaller proportion to the solids than in any other temperament. Very little fat is deposited. The person looks dry and thin; presenting angular and harsh outlines. The veins are very prominent on the surface. The muscles start out boldly, and are divided by deep depressions, even in the face, giving a strongly marked character to the countenance. The skin is dry and tightly drawn; the flesh hard, and the animal heat great, or even burning. The density of the blood seems to deepen the colour of the hair and eyes, which are dark, and often black. The complexion is usually swarthy.

723. Men of the bilious temperament have firmer, more

energetic, and therefore less excitable nerves than those of the former class. But all the vital operations, though somewhat slow, are performed with great power and certainty. Mentally and physically, they are capable of long continued and untiring exertion. Their passions and their affections partake of this character. They are fond of schemes demanding much time for their accomplishment; and pursue their object, whether in love, hate, science, war, or business, with the long trot of the wolf.

724. *The lymphatic or phlegmatic temperament* is characterized by the superabundance of the cellular tissue and serous fluids of the body, and is generally attributed to an excessive influence of the lymphatic system. This evidently marks an inferior degree of organization—a general deficiency of development—and it is the reverse condition to that remarked in the bilious temperament. The person is soft and disposed to be flabby; there is a great absence of tone; the surface is pale, moist, and cool; the hair and eyes are very light; the countenance unexpressive; and the temper imperturbable, in cases which are very strongly marked. It is hardly necessary to state that those who have this temperament naturally and very completely matured, are peculiarly averse to mental and bodily exertion. The blood has a superabundance of serum, and the frame is not supplied with proper nourishment; and of course, the nervous susceptibility cannot be considerable.

725. *The nervous temperament* has been added to the list in modern times, and its most peculiar characteristic appears to be a peculiar liveliness of nervous susceptibility without a corresponding energy of the muscular contractility. This condition is the reverse of that found in the athletic, (which might be erected into a *muscular temperament*,) and is common to those of sedentary or luxurious habits. It is perhaps more frequently *acquired* than *inherited* or constitutional. The nervous fibres in this temperament are not unduly developed; for this would give them firmness and render them less susceptible. When *acquired*, the nervous excitability is probably

due to an increased flow of blood towards the nerves, in consequence of their frequent and unnatural stimulation. This condition is sometimes induced by studies of too intense a character, or too long continued, and also by sensual indulgence. It is not an uncommon infliction upon the poet, the scholar, and the dissipated, and may be either a cause or a consequence of their indulgences.

726. The nervous temperament is consistent with great mental effort, particularly in the higher walks of literature and the forum. When constitutional, it is more than probable that the nerves are really weaker, or less thoroughly nourished than they should be; for debility of this kind is well known to superinduce increased susceptibility. It acts like a magnifying glass upon both the ills and the pleasures of life, and rarely proves a blessing.

727. A temperament partaking of the nervous, but also marked by an excess of the cellular tissue in a vigorous condition, and not in the feeble state presented in the phlegmatic temperament, is natural to children and women. The same nervous susceptibility with the rapidity of judgment and the evanescence of impressions dependent upon it, as well as the same soft condition of the nervous fibre, mentioned in the last paragraph—is also proper to childhood and to the female sex.

728. Now these several temperaments being capable of change by local circumstances, may be corrected by judicious education and habits when they are productive of evil by their excess. Should I ever address you upon the subject of Hygiene, or the art of preserving health, there will be much to be said upon this subject, but at present, it is sufficient to introduce two illustrations.

729. The *proper use* of muscular exercise, carried to that extent which will give full developement to the muscles, will often correct a nervous temperament into a nervo-bilious or nervo-sanguine one, to the great advantage of the individual; and the bilious or sanguine may sink by idleness and mental inactivity into the phlegmatic, to his great disgrace.

730. Now, as the principal general temperaments depend upon the peculiar condition of some one system of organs or tissues, either the vascular, the lymphatic, the nervous, or the cellular; as portions of all these systems enter into the construction of most organs; and, as an excess of either of them in any one organ must constitute a peculiar *local temperament*; it follows that the greater part of the frame may display all the signs of one temperament, while some individual organ,—the brain, for instance,—may exhibit another.

731. But the brain is not subject to our observation. We cannot tell what is its local temperament by craniology; and our only guide is the observation of the conduct of the person as compared with his general temperament. This fact seems to have been overlooked by the phrenologists when they have undertaken to estimate the relative capacities of different men, by the total bulk of the brain.

732. A peculiar local temperament of a single organ, often leads not only to a general alteration of the balance of life, but also to strange and unusual tastes, which cannot be disregarded with impunity. An *idiosyncrasy* is defined to be a peculiarity of constitution which causes a remedy or any other agent to act upon a particular individual, as it would not do upon the generality of men. Thus, some people faint at the smell of a rose, and eating bitter almonds or crabs affects others with a nettle rash. Now, although many idiosyncrasies *may* result from other causes, many others certainly do form peculiar temperaments of some one or more organs. We should be cautious, then, in blaming others for an obstinate adherence to certain apparently whimsical habits of diet or other singularities in their mode of life.

733. And now, having completed this outline of some of the chief principles of physiology, I bid my young readers adieu, in the hope that it will prove a useful guide to them in the studies and duties of future life.

QUESTIONS FOR PUPILS.

CHAPTER I.

Is motion a proof of life? Give some instances of motion in inanimate things,.....	PAR. 2
Is rest a proof of the absence of life? What is an eye-stone?	3
Is growth a sign of life? Give instances of growth in things that have not life,.....	4, 5, 6, 7
Give instances of minerals appearing to grow like plants,...	8, 9
Are motion and growth sufficient of themselves to distinguish <i>things that have not life, from living things?</i>	10
Are birth and death distinctive properties of living things?..	11
What is the first step in Physiology? What is Physiology?	11
Explain the differences between the motions of living things and those of things that are not alive. Can the latter ever move by their own efforts? Give examples of motion in inanimate things, and the causes that produce them. What is said of the fall of a stone, the vibration of a spring, the clicking of a watch, the crawling of an eye-stone?.....	13
Are living things moved by external agents? Give examples,	14
Give proofs of motion in living things from a power within themselves. Why do vegetables, when sprouting, direct their shoots toward the light, and their roots toward the nearest moist earth?.....	15
Give further proofs from the effect of light upon the leaves and flowers of plants. What is there curious in the history of the plant called Venus's fly-trap?.....	16
Do animals, as well as plants, display this internal power?..	17
Is this power of regulating their own actions possessed by <i>any thing</i> that has not life?.....	18
Why is an apparatus or machine necessary to all living things? What is an <i>organ</i> ? Give some examples of organs in living things,.....	19
Why are animate things called <i>organized beings</i> ?.....	20
Whence do organized beings derive the matter of which they are formed? What is meant by the <i>organization</i> of such beings?.....	21

What is <i>organic matter</i> ? and what is <i>inorganic matter</i> ?	22
What are <i>organic remains</i> ? and what are petrifications?	23
What is meant by the term <i>system</i> , as applied to organization?	
Give some examples of systems,	24
Is it proper to apply the term <i>system</i> to the body?	25
Explain the manner of <i>growth</i> as observed in organic bodies.	
Do inorganic bodies ever grow by adding particles to their interior, or by changing their nature so as to appropriate them to their own use?	27
Explain the manner of <i>growth</i> as observed in organized beings.	
Do either plants or animals grow by adding matter to their exterior? How are the bark of trees and the cuticle of animals replaced as they wear away?	28-29
How are trees nourished? and how is man?	30
Give some proofs that plants and animals can convert other things into their own nature,	31
Give some proof that plants and animals possess the power of moving their fluids from place to place within their frame,	32
Explain the difference between the mode of growth of a plant, and the seeming growth of a sponge when placed in water,	33-34
Explain the seeming growth of metals when heated,	35
Can we explain what is life? Does death produce any instantaneous change in the organization?	36-37

CHAPTER II.

What proof is there that each of the different parts of an organized being is possessed of its own peculiar mode of life? What is meant by <i>the vital powers</i> ?	38
What is meant by the term <i>function</i> ? What by the term <i>vital functions</i> ?	39
Can the different parts of an organized being preserve their life in all cases, when separated from the body? Is the integrity of all the parts generally necessary to the health of the whole?	40
Give some proof that the sound condition of certain parts is indispensable to life in complex organized beings, while certain other parts can be removed with impunity, or even with seeming advantage to health,	41
Why do small wounds often occasion the death of a plant or animal? Give some examples. Why are not such wounds always fatal?	42
Give instances of the retention of life for some time, or permanently, by parts cut off from the body of an animal. What are you told of the earth-worm?	43
What is said of the vitality of the tail of the snake?—the hind legs of bull-frogs?—the head of the snapping turtle?—the tortoise, and the shark?	44-45

What relation exists between the simplicity of organization and the retention of life in separated parts? Why is the health of the whole body less dependent on the health of the parts in the simple animals?..... 46

Are the fluid parts of animals organized?—What is meant by *assimilation*?.....47, 48

Does the simplicity of the blood or sap appear to correspond with the simplicity of the organized being in which it is found? Does sap ever contain globules?..... 49

Are there any plants containing substances resembling animal matter?..... 50

Is the blood of the simpler animals like to that of the more complex?.....51-54-55

What is said of the fluids of the medusa?..... 52

What is said of the structure and motions of the medusa?.... 53

What reason can you now give for the preservation of life in parts cut off from the simple animals?..... 56

What is said of the structure of the hydra, its stomach, its arms, and the motion of its food during digestion?..... 57

What is meant by digestion? and by what means does the hydra appear to digest its food?..... 58

How is the frame of the hydra nourished?.....59-60

What consequences follow when a hydra is turned inside out, like the finger of a glove? and what do they prove?..... 61

What is said of the extent to which a hydra may be divided, naturally or artificially, without destroying its life?.....62-64

What is said of the *organization of the hydra*?..... 65

What is meant by the terms cellular membrane and cellular tissue?.....66-67

Is cellular tissue found in all animals?—What is its structure as seen under the microscope?—What is its appearance when seen beneath the skin of animals?..... 68

Give some proofs that the cells of this tissue communicate with each other, from the mode of preparing animals for the market, and from the history of wounds of the lungs,....67-68

What is the structure and appearance of fat?—What name is given to the membrane that contains fat, by most writers? 71

Does the skin of the hydra differ from cellular tissue?..... 72

How does this animal digest, absorb, and breathe?.....73-74

How does the hydra preserve its form, and how does it perform its motions?..... 75

Has it volition? Give some proofs,.....76-77

Is there much resemblance between the simplest vegetables and the simplest animals?..... 78

CHAPTER III.

Why are the simplest animals necessarily small?..... 79

Why are they seldom found except in the water?..... 80

- To what class of animals does the zoanthus belong?—What is the name of the arms by which polypi take their prey?.. 81
- What are cilia?—What their uses? and why do polypi generally require them?.....81-82
- How are the cilia arranged in the flustra?..... 83
- How are they arranged in the vorticella?..... 84.
- Is the motion of cilia like that of muscles in the larger animals? Give a reason for your opinion,..... 85
- Are cilia seen in animals much more complex than the polypi? Give an example. Are the cilia designed principally for taking food in the more complex animals?..... 86
- Are any thing like cilia found in vegetables? Give an example. Describe the cause of circulation in the chara-hispida,..... 87
- In what respects do polypi resemble plants? What name is given to their buds? How do the gemmules move from place to place? How do they choose their permanent residence? Is the motion of their cilia voluntary?..... 88
- Can many polypi, living in communities, enjoy common life? 89
- How do these communities construct their habitations? Describe the form of the support of the community in sertularia, in tubipora, in red coral and gorgonia, in madreporas. How are coral rocks formed?.....89-94
- What is meant by the term secretion? Give examples, from polypi, from man, from shell-fish, reptiles, and the higher orders of animals. What is meant by ossification?.....94-98
- What is nutrition?..... 99
- Give examples of fluid secretions and their uses,..... 100
- What is meant by the term *functions of organic life*? and what by the term *functions of animal life*?..... 101
- By what power is the blood driven from place to place, in order to nourish the frame of animals?..... 102
- Is contractility a function of organic life?..... 163
- Give examples of contractility in plants and animals,..... 104
- Describe the physalia, and its contractility,.....105-109
- What is the cause of the pain felt on touching the physalia? 107
- Is vital contractility dependent on the will?.....110-111
- What parts of animal bodies display contractility?..... 111
- Does contractility display itself without excitement? Give examples of its being excited by the will, and by other agents,..... 112
- What is meant by a stimulant?..... 113
- What is meant by *tonicity*? What is *tone*? Give examples from the history of palsy, and sleep. Give examples of tonicity of the skin, and of the vessels, in fainting,....116-118
- Is there more than one kind of contractility?..... 119

CHAPTER IV.

Why is the stomach ramified in many medusæ, and how? 121-123

What is meant by mastication, and masticatory apparatus?..	124
Do you find teeth and jaws among the lower orders of animals?	125
Are the masticatory organs always seated near the mouth?	
What is said of the lobster? and of shell-fish?.....	126
What is the alimentary canal?.....	127
What name is given to masticatory organs attached to the alimentary canal?... ..	128
In what classes of animals are <i>gizzards</i> generally found? How do fowls supply the want of teeth?.....	129
In what animals is the alimentary canal more simple, and in what animals more complex? Give a reason for the difference, and examples from shell-fish, from fishes and birds, from beasts that chew the cud, and from the camel,....	130-132

CHAPTER V.

Why is a muscular system necessary in the economy of animals of complex organization?.....	133
Give an example of the great force with which muscles may contract?.....	133
Is the strength of a muscle dependent upon its vitality?.....	133
Has the alimentary canal any muscles connected with it? and if so, for what purpose?.....	134
How do the occasional contractions of muscles, when put in motion, differ from the constant contraction of almost all parts of the body, called tone?.....	134
Why do some muscles act under the government of the will, and others involuntarily?.....	135-136
To what class of functions do the involuntary muscles contribute? and why are they called muscles of organic life?...	137
Why are certain muscles called muscles of animal life?.....	137
What is meant by the mixed muscles?.....	138
What is a fascia? Where are fasciæ found?.....	139
Are the various fasciæ separate or connected together?.....	140
What are the principal uses of fasciæ, and how are they composed?.....	141-142
What would be the appearance of the fasciæ if all other parts of the body were removed, and they alone were left?.....	142
What is flesh? What is a muscle? What constitutes the muscular system?.....	143
How are muscles generally attached? By what are they enveloped and surrounded?.....	144-145
What is said of the structure of muscles? of their colour in different animals, and of the cause of cramp? Is every fibre of a muscle a distinct organ?.....	146-147
What is said to be the appearance of muscular fibre under the microscope?.....	148

- What part does the cellular tissue play in the construction of a muscle?..... 149
- What change takes place in a muscle when it happens to be caught between the broken extremities of a fractured bone? 150
- Why do muscles generally require solid attachments in order to move the body? What is said of muscular attachments to the skin, and of the motions of the common snail? Do the fasciæ ever furnish attachments to muscular fibres?... 151
- What is said of the muscular motion of the snail?..... 151
- What is said of the formation of the shells of shell-fish, and their muscular motions?..... 152
- What is said of the muscular motions of the echinodermata? 153-154
- How are the voluntary muscles attached in the crustacea and insects?..... 155-156
- What parts of the more perfect animals resemble the external skeletons of the testacea, crustacea, echinodermata, and insects?..... 156
- Why would external skeletons be inconvenient to the higher classes of animals?..... 157
- What great classes of animals are provided with internal skeletons? What name is given to the system of solid organs composing the internal skeleton?..... 157
- How are the muscles attached in animals that have an osseous system? Is any thing like true bone found in the inferior animals?..... 158
- What is the condition of bone in very early life? What proof is given of the softness of the bones in children? What kind of matter is afterwards deposited in them? Of what substances are the bones of the shark and many other fishes composed?..... 159
- What substance is added to give hardness to the bones of the most perfect animals?..... 160
- What effect is produced upon perfect bone by burning it or boiling it a long time?..... 161
- What by soaking in an acid?..... 162
- Can bone be reduced to cellular tissue by art?..... 163
- Can it be so reduced by disease? Give instances,..... 164
- What is the general importance of the cellular tissue in all the special organs of animals? and especially in young animals?..... 165-166
- When wounds are received, what part is it that unites first? 167
- Why does cellular tissue form bone in one part of the body, muscle in another, &c.?..... 168
- What are the *articular cartilages* and their uses? Give an example of the articular cartilages,..... 169-171
- What are the *synovial membranes*, their use and attachments?..... 172
- What is *synovia*, and its use?..... 172
- What are the *ligaments* and their uses?..... 173

Describe a ligament and its structure,.....	174
What is the principal function of ligaments?.....	174
Give an illustration. What happens to ligaments when joints are put out of place or dislocated?.....	174
What is the periosteum?.....	175
What is the periosteum of the articular cartilages called? and what name is given to the periosteum of the outer side of the skull?.....	176
Name the classes of organs belonging or appended to the osseous system,.....	177
What is the appearance, structure, and use of <i>tendon</i> ?....	178-179
Can tendons contract like muscles? Describe the mechanical arrangement of tendons, and particularly that of an oblique muscle of the eye,.....	180
Describe the character of the involuntary muscles, and the action of the muscular coat of the stomach,.....	181

CHAPTER VI.

What are the <i>blood-vessels</i> ? What do they contain, and why are they necessary in animals of complex organization?...	182
What blood-vessels are called <i>veins</i> ?.....	183
How do the <i>valves</i> of the veins effect the course of the blood?	184
What is the form of the common centre toward which the blood in the veins flows, in insects and worms? What is its character, and what is it called in the higher orders of animals?.....	185
What are the <i>arteries</i> ? and what is their use?.....	186
How are the arteries distributed?.....	186
Explain the necessity of a connexion between the arteries and veins,.....	187
Describe the capillary blood-vessels,.....	187
What is the circulation?.....	188
What are you told of the gradual additions of systems of organs as animals rise in the scale of nature? Has the earth-worm a circulation?.....	189
What kind of circulation have insects?.....	190
What is said of the circulation in the leech and the oyster?..	191
How does nourishment find its way into the circulation of the simplest animals that have a circulation?.....	192-193
What is meant by the term <i>chyme</i> ?.....	193
Is the assimilation of chyme complete when it first enters the body from the alimentary canal?.....	194
What is chyme called after it has been imbibed or absorbed into the body?.....	194
Is chyle precisely similar to the blood, when it first mingles with that fluid?.....	194

- How does the chyle reach the blood in the higher orders of animals? Are the *lacteals* a component part of the circulatory apparatus?..... 195
- What is the colour of chyle? Is it organized?..... 196
- What is the mode of origin and the route of the lacteals? Where and how do they empty their contents?..... 197
- What prevents the chyle from flowing the wrong way in the lacteals?..... 198
- What is the structure of a lymphatic gland?..... 199
- Why cannot pieces cut from most animals continue to live independently?..... 200
- Is there any other route by which substances reach the circulation in the higher orders of animals, besides the lacteals? Give proofs,..... 201
- Is there any reason to believe that cellular tissue and the veins preserve their power of absorbing things in the higher orders of animals, as they appear to do in the lower orders? 202
- What are the *lymphatics*? and what is lymph?..... 203
- In what direction does the lymph flow? What is the course of the lymphatics? and where do they empty their contents? 203
- Give a proof, from the history of poisoned wounds, that the lymphatics do actually convey substances into the circulation,..... 204
- Are lymphatics found in the lower orders of animals? What is meant by *the absorbent system*? What by the *absorbents*? 206

CHAPTER VII.

- Why does a young animal require proportionally more food than an adult?..... 208
- Why does an adult require any food at all?..... 208-211
- Can the wearing away of the skin and its appendages account for this want?..... 208
- What is *perspiration*? Give examples from plants and from animals. Why do we not see liquid perspiration on the surface of all animals at all times? By what means can you make it obvious at any time? What is *insensible perspiration*?..... 209
- Give some proof that a process analogous to perspiration is going on at all times in the cavities of the animal body,... 210
- Is the quantity of perspiration considerable? From what fluid is it formed? By what means is this constant loss of substance compensated?..... 211
- Mention some other secretions that continually exhaust the blood, and make food necessary to the adult,..... 212
- Why are sick persons often able to go long without food?... 213
- In the history of the effects of starvation, what is the most

obvious cause of death when animals are totally deprived of food?.....213-215

What effects in addition to the exhaustion of fluids follow partial starvation? and are these effects seen in persons labouring under fever?..... 215

Can a man be virtually starved by disease, though still able to take food and plentifully supplied with it? Give a case, 215

By what route are solid portions of the frame carried out of the body? What is meant by the assertion that a starving animal lives upon itself?..... 216

Does the same kind of constant absorption of solid parts observed during disease or starvation continue during health and plenty?..... 217

Why are not the organs of an animal constantly rendered smaller by absorption? Why do the organs of a young animal constantly increase in size?..... 218

Are any of the particles that compose an animal body permanent during life? What will be the condition of your bodies in a few years?..... 218

What purposes are answered by the secretions in purifying the blood?..... 219

Name some of the secretions that assist in purifying the blood,..... 220

Why do the blood-vessels secrete different fluids in different places?..... 221

What points of general resemblance are found in the different secreting organs? Give examples,..... 222

What name is given to the special secreting organs?..... 223

How are the blood-vessels arranged in the secretory glands? 224

What are the form and function of the secretory ducts?..... 225

Can we trace any direct connexion between the capillaries and the ducts of secretory glands? What is meant by transpiration? Does transpiration prove a functional resemblance between the human cellular tissue and that which seems to form the entire body of many of the inferior animals?..... 226

Are the secretions ever rendered useful for special purposes in the animal economy, other than the purification of the blood? Give proofs from the history of the tears, the saliva, and the bile,..... 227

What is *respiration*? Do plants respire?..... 228

What is the principal object of respiration in animals?..... 229

What are the principal ingredients of animal matter?..... 230

How are the surplus oxygen, hydrogen, and nitrogen of the blood removed from the body?..... 231

How is the surplus carbon of the blood chiefly removed, and what is the chief function of the *respiratory apparatus*?... 232

Describe the process by which the respiratory organs separate the carbon from the blood, and the result of that process,... 233

Do fish and other aquatic animals breathe water?..... 234

- Can animals live in pure oxygen? Can air contain too much oxygen to be healthful?..... 235
- Is actual contact between the atmospheric air and blood necessary for respiration?..... 236
- By what means is the function of respiration performed in the simplest animals? What is said of the toad in this respect? 237
- Does man breathe by his skin? What has this to do with cleanliness?..... 238
- Describe the general plan on which the special respiratory organs of those animals that have such an apparatus, are formed,..... 239
- What is the arrangement of the respiratory capillaries? How are the respiratory organs generally situated?..... 240
- What organs in insects are called *tracheæ*? and what is meant by *tracheal respiration*?..... 241
- What is the general plan of organization in the respiratory apparatus of aquatic animals? What is their construction in fishes?..... 242
- What term is given to the aquatic breathing organs? What is *branchial respiration*?..... 243
- How do the branchia act in accomplishing respiration?..... 244
- Describe *the branchia* of the common fresh-water mussel, and the agency of the cilia in respiration,..... 245
- What name is given to the respiratory organs of animals that live in air? What is meant by pulmonary respiration?... 246
- Describe *the pulmonary cavities* and breathing organs of the *Lymnæa*, and its mode of breathing,..... 247
- Describe the arrangement of its respiratory capillaries,...247-248
- Describe the construction of the respiratory cavities of the larger animals, their air-cells, and capillaries. State the position of *the right and left lungs*,..... 249
- Describe the arrangement of the canal or duct that admits air to the lungs, from the back part of the mouth to the air-cells, 250
- What canal is called *trachea* in the larger animals? What are the *branchia*? What are the bronchial tubes?..... 251
- If we compare the lungs to a secretory gland, what appendages of the glands would correspond with the air passages? What lines these canals? What do they contain? How are they kept open?..... 252
- What part do the ribs and certain muscles play in pulmonary respiration? What is *inspiration*? and what is *expiration*? 253
- What additional part in respiration is played by the bones of birds?..... 254
- What change in the mode of respiration takes place as a tadpole is changed into a frog?..... 255
- Does all the blood of the inferior orders of animals pass through their respiratory organs? Describe the mode in which the blood passes to these organs in such animals,..... 256

- What effect has the imperfect respiration of inferior animals on their vital functions?..... 257
- Does all the blood of the superior orders of animals pass through their lungs? What is the effect on their vital functions? 258
- What are the nutritive arteries of the respiratory organs, and why are they necessary?..... 259
- How do the two sets of veins belonging to the lungs or branchiæ dispose of their blood?..... 259
- Are the terms *branchial vessels*, *respiratory vessels*, and *pulmonary vessels* applied to the nutritive vessels?..... 259
- By what term is the system of vessels that nourish the body distinguished from the respiratory system?..... 260
- Describe the manner in which the human heart and that of most of the larger animals is divided into four cavities. Is the division between the right and left sides of the heart complete or incomplete?..... 261
- Is the division between the two cavities on the left side complete or incomplete? Where do you find valves between the cavities of the heart? What is the structure of the valves? What their attachments?..... 261
- What names are given to the four cavities of the heart?..... 262
- From what vessels do the auricles receive their blood? How do they dispose of it?..... 262
- What vessels have their origin from the ventricles?..... 262
- What happens to the valves of the heart when the ventricles contract? Are the arteries provided with valves? Why does not the blood flow back into the veins instead of passing into the ventricles when the auricles contract?..... 262
- What is the name of the great venous trunk coming from the head and upper extremities? What kind of blood does it contain? What vessel brings back to the heart the blood from the body and lower extremities? Are these vessels united into one? How do they communicate with the heart? 263
- Describe the entire route of the circulation, beginning at the right ventricle and following the course of the blood till it reaches the same cavity again,..... 264
- What kind of blood is found in the right side of the heart, and in all the arteries and veins leading to and from it? What kind of blood is found in the left side and its vessels? How is the heart itself nourished?..... 265
- Can the heart be regarded as more than one organ?..... 266
- Why are the left auricle and right ventricle called *pulmonary*? Why are the right auricle and left ventricle often called *systematic*?..... 267
- Is there such a thing as a double circulation? What parts constitute the *respiratory or pulmonary circulatory apparatus*? what the *general or nutritive circulatory apparatus*?..... 267
- Explain how the supply of blood is maintained in any part of the body when any of its principal blood-vessels are totally

- obstructed by disease or accident. What is the meaning of anastomosis? 268
- What danger results from tying a very large artery? What happens when all the arteries or all the veins of a part are obstructed? 268-269
- What class of organs contain most capillaries? At what age are the capillaries largest and most numerous? 270
- Why do the young require more food, (proportionally,) than older persons? 270
- Why does muscular exercise render the muscles larger and stronger? Why does it make the heart beat more rapidly? Does employment produce the same effect on other organs? Why does exercise hasten the breathing? 271
- What is the condition of the capillaries in muscles while employed? 272
- What is the effect of permanent rest on muscles? Give examples, 273
- Do the same rules hold good in relation to the paramount rest of other organs? Why does something like fever come on after dinner? What effect does thinking produce on the capillaries of the brain? What moral and hygienic deductions are drawn from the facts stated in relation to employment and rest? 274
- Can any organ endure constant exercise? Explain how the heart obtains rest, 275
- Illustrate the necessity of rest by the history of the effects of travelling on nutrition in man and horse, 276
- Explain the effects of sleep on nutrition. Those of late sleepers. What bad effects may follow, bodily and mentally, from loss of sleep? At what age is most sleep required? and why? 277
- Explain the effects of different degrees of over-exertion on the nutrition and functions of organs. Give examples, 278
- Explain the effect of over-exertion with deficient sleep, rest, and food on the young in certain conditions of society, 279
- What have the organs themselves to do with completing the process of nutrition? 280

CHAPTER VIII.

- Why is a common mean of communication necessary between the different organs of organic life? What system supplies this necessity? 281
- In what animals do we first detect any thing like nerves? What are the first signs or rudiments of a nervous system observed among the simpler animals? In what classes of animals is the nervous system studied to the best advantage? 282

Describe the appearance and give the names of the two kinds of matter principally composing the nervous system,..... 283

What is the composition of the brain, and the arrangement of its two nervous ingredients?..... 284

What is the condition of the cellular membrane in the brain? 285

What is the consistence of nervous matter in the brain? How is it protected from injury?..... 286

What are the *ganglia*?..... 287

Are there nervous filaments in the brain and ganglia? Are the brain and ganglia called nerves? What are they called? How are the nerves connected with them? What is the special function of the nervous centres?..... 288

What is a nerve? What kind of covering is given to a nerve by the cellular tissue? How are the nervous filaments covered?..... 289

Is a nerve a single or a complex organ?..... 290

Is each primary nervous trunk endowed with more than one function? Give illustrations of the different functions of different primary nerves,..... 291

How are compound nervous cords formed? What effect has their complexity on their functions? Are the functions of the filaments of compound nerves affected by this complexity?..... 292

Give an account of the origin and junction of nerves of feeling and voluntary motion, with the effects of dividing the primary trunks or the secondary trunks of one of those nerves, 292

Describe what is meant by a *plexus*, and its effect upon the functions of the nerves that result from it,..... 293

Describe how a ganglion appears to be connected with its nerves. Does a ganglion add any thing to a nerve?.... 294

What appears to be the condition of nervous filaments when they pass through ganglia?..... 295

What effect has a ganglion on the functions of the filaments of the nerves connected with it?..... 296

How would you prove that blood-vessels and absorbents form a part of every animal organ of which we know the structure?..... 297

Are the functions of animal organs dependent on their blood-vessels?..... 298

Are the functions of animal organs dependent on the nerves? Give proofs,..... 299

How is the nervous system divided into minor systems, and what are they called?..... 300

Describe the location and general arrangement of the nervous system of organic life,..... 301

Are the organs supplied by the nerves of organic life and those nerves themselves arranged regularly in corresponding pairs?..... 301-302

- What is the general arrangement of the nervous system of animal life, and the organs supplied by it?..... 303
- Describe the general arrangement and connexions of the sympathetic nerve of those animals that have an internal skeleton,..... 304
- Describe what degree of connexion exists between the nervous system of organic life, and the will and sense of feeling in an animal,..... 305
- Describe the mode in which the nerves of organic life influence those of animal life in sickness,..... 306
- Give instances of the mutual influence of the two grand divisions of the nervous system, as displayed in accidents, in distentions of the stomach, and in intestinal irritations,.... 307
- What name do we give to the cause of these associated physiological actions? and what do we know about this cause? 308
- Describe the immediate effects of an impression upon a ganglionic nerve. Describe the secondary effects when more than one ganglion, or the whole nervous system of organic life is interested. Describe the general effects when the nervous system of animal life is involved in the impression, 309
- Give proofs of the influence of strong impressions on the brain, producing serious effects on the nervous system of organic life, and the organs under its control,..... 310
- Give proofs of the mutual dependence of the nerves and the blood-vessels on each other,..... 311
- What moral conclusions can you draw from the unity of the human frame, which inculcate the importance of the study of physiology,..... 312
- Is there any proper brain in the animals that have no bony skeleton? Whence are their nerves of special senses derived? What is it that physiologists generally mean when they speak of their brain?..... 313
- Have we solid ground for asserting the existence of nervous matter in the most simple animals?..... 314
- With what system of nerves in man can you compare the simplest forms of the nervous system in the lower orders of animals? Which set of functions,—the organic or the animal,—are brought to high perfection at the earlier stage in the progress of animal developement?..... 315
- Are the simplest animals possessed of senses, instinct, and volition? What inference can you draw from the facts just mentioned, as to the probable functions of the seemingly simple nervous systems of the lower orders of animals that have no internal skeleton,..... 315
- What say you can be the origin of the obvious functions of animal life, in beings that present no signs of nervous matter whatever?..... 315
- What is said on the possibility of comparing the nervous systems of animals that have no bony skeleton, with those of

- animals that have such an apparatus, with a view to throw light on the functions of the brain in man?..... 316
- What is said of the propriety of the term *scale or chain of nature*, so often employed by writers, and used for convenience even in this volume?..... 317

CHAPTER IX.

- What are the principal regions into which the body is divided?.....319-320
- Describe the bounds of the part of the head which contains the brain. What do you understand to be the meaning of the word *cranium*?..... 321
- What part of the head is called the face? Does it include the forehead?..... 322
- How do anatomists use the term neck?..... 323
- How is the trunk divided? Describe the boundaries of the chest and the abdomen,..... 324
- What part of the trunk is called the pelvis?..... 325
- What are the principal contents of the chest?..... 326
- What are the principal contents of the abdomen?..... 327
- What do you understand by the terms shoulder, and shoulder-joint?..... 328
- What do anatomists understand as the arm? and what is called the forearm?..... 329
- What is said of the fundamental structure of the whole body? 330
- What is said of the manner in which the organs are formed? 332
- What is said of the complex structure of the human skin?... 335
- What names are given to the outer layer of the skin? Is it organized? Has it any feeling?..... 336
- Is the cuticle of uniform thickness?..... 337
- What is said of the resemblance of the nails and other cutaneous appendages to the cuticle?.....337-338
- What is the origin and early condition of cuticle?..... 339
- Has the cuticle any pores? What causes its irregularity of surface?..... 340
- What are the follicles of the skin called? What their structure? What their function?.....341-342
- What relation has the cuticle to the follicles?..... 343
- Where is the origin and what the mode of growth of the hairs?.....344-345
- What are the connections of the hairs with the cuticle?..... 346
- What remarks are made on the colour of the hair?..... 347
- What are the functions of the cuticle? Are they active or passive?..... 348
- What kind of a membrane lies next below the cuticle?..... 349
- What is meant by the term *papillæ* of the skin? What is the name given to the middle membrane of the skin? What

- is said of the cause of differences of complexion in individuals?..... 350
- What is said of the influence of climate and exposure upon the hues of races of men?..... 351
- What parts, other than the rete mucosum, are tinged with the same colouring matter? What proofs are there of the influence of climate and the seasons on the colour of quadrupeds, fishes and birds?..... 352
- What is the name of the inner layer of the skin? What is the papillary body?..... 353
- Of what is the true skin composed? Describe the manner of its organization,..... 354
- What is the arrangement of the nervous matter and the nerves on the outer surface of the true skin? What is the function of the papillæ? What is the common cause of the severity of the pain in inflammations of the true skin? What causes the commencement of mortification in carbuncle?..... 355
- What are the situation, structure and function of the bulbs of the hairs?..... 356
- What are the principal functions of the true skin? What are the causes and nature of goose-flesh? What is the condition of the sensibility of the skin in goose-flesh?..... 357
- What is the name given to the muscular coat of the skin found in many animals? What is its structure? What its function? What example is drawn from the history of the elephant?..... 358
- What has the muscular coat to do with the motion of the hair and feathers in quadrupeds and birds?..... 359
- Has the skin in man any muscular coat?..... 360
- What do you understand by the term integuments?..... 361
- By what means are the different layers of the integuments converted into one apparently simple envelope for the body? 362
- What are the connections of the integuments with the parts beneath them? Where are the connections most firm and close?..... 363
- What is meant, in common language, by the term *fleshy*, as applied to personal appearance? Why do not the palms of the hands, and the soles of the feet, become as fleshy as other parts?..... 364
- What is said of the general formation of all the internal passages of the body?..... 365
- What happens to the external integuments when they approach the mouth and nose? What happens to the blood-vessels of the true skin? What to the cuticle? What name is given to the cuticle within the mouth and nose?..... 366
- What change takes place in the function of the follicles, when placed within the mouth? Is there any radical difference between the internal and external integuments?..... 367
- What part of the throat is called the pharynx? What is the

arrangement of its muscular coat? What is the œsophagus?
 How is its muscular coat arranged? How does the œso-
 phagus terminate?..... 368

Where does the internal cuticle or epithelium of the alimen-
 tary canal terminate? What is the extent of the mucous
 membrane of the alimentary canal?..... 369

What is said of the capillary blood-vessels of the mucous
 coat?..... 370

What are the villi? To what part of the external integuments
 do they correspond?..... 371

What is said of the mucous follicles and mucous glands?... 372

What is said of the difference of the arrangement of the sever-
 al layers of the internal and the external integuments?... 373

What have the integuments to do with the ducts of the secre-
 tory glands? What is said of the gall duct? What of the
 integuments entering the air-passage? What of the duct
 conveying the tears to the nose?..... 374

What is said of artificial or accidental ducts formed by the
 integuments? What is the nature of a fistula? Describe
 the mode of curing a salivary fistula,..... 375

What circumstances may convert a portion of the internal
 integuments into common skin, or a portion of the common
 skin into mucous membrane?..... 376

What is said of the causes and cure of excoriations in fat per-
 sons and those who neglect cleanliness, when the skin folds
 upon itself and excludes the light and air?..... 377

What resemblance is mentioned between the integuments of
 man and the polypi and the hydra?..... 378

Is there any deficiency of the integuments or passage through
 them internally or externally?..... 379

Why are the internal more liable to irritation than the external
 integuments? Why are they less subject to pain?..... 380

What particular portions of the surface are most sensitive, and
 why is sensation concentrated in them?..... 380

What is said of the irritability of the orifice of the larynx?.. 381

What is the cause of suffocation in drowning and in poisonous
 gases?..... 382

What proof is there that the health of the lungs requires fre-
 quent ablutions? Mention one of the causes of the good
 effects of rubbing with the coarse towel, and wearing flannel, 383

CHAPTER X.

Why are the pieces of the skeleton more numerous in child-
 hood?..... 385

How many bones are there in the skeleton of an adult? On
 what plan are they constructed? Into what great classes
 are they divided? What fills the cavities in their sub-
 stance?..... 386

- Describe the interior and exterior arrangement of the bones in general terms,..... 387
- What do you understand by the *tables* of the bones of the cranium? What name is given to the bony cellular structure between these tables? Which of the tables is usually the thicker?..... 388
- What is the arrangement of the walls of the long bones?.... 389
- What is the general arrangement of the bony matter within the long bones? What do you mean by the medullary cavity of most long bones, and where do you find it?..... 390
- Is the medullary matter of bones formed anywhere but in the medullary cavity?.....386-390
- Describe the mechanical advantages derived from the peculiar arrangement of the bony matter in the centre and at the extremities of the long bones,..... 390
- State the several names given by anatomists to the looser texture in the interior of the bones,..... 391
- Why is it difficult to display the existence of cellular tissue in the substance of bone?..... 392
- How is the cellular tissue arranged in the cancellated structure? 393
- Are there any passages in the solid parts of bone? Can you see them? Describe their arrangement in the shafts of the long bones and in the short bones,..... 394
- What effect does burning or long exposure produce on the appearance of the bones? What is the real internal structure of the solid portions of bone? What occasions the appearance of a tabular arrangement? Is there any medullary matter in the solid portions of bone? How can you prove this?..... 395
- How do the blood-vessels find their way into the interior of the bones? Where are they most numerous, and where most rare? What classes of bones are supplied with one or more large blood-vessels? What are the distribution and functions of those blood-vessels?..... 396
- Is bone possessed of the sense of feeling? Is the marrow? 397
- Are the bones living organs? How do you know them to be so?..... 398
- What is the *cranium*? How many bones compose it? Do any of them assist in forming the face? What is the general form of the cranium? Describe the general form of its cavity and walls. How many great depressions are there on its lower surface?..... 399
- What are the name, position, and general form of the anterior bone of the cranium?..... 400
- What are the *frontal sinuses*, and where are they formed? Describe their connexions and use?..... 401
- What is said of their character in childhood, and in women? What of their size, and relation to craniology?..... 402

What occasions <i>the staggers</i> in sheep and deer? Does the same accident ever happen to man?.....	403
Describe the orbital plates of the frontal bone,.....	404
What class of organs do the phrenologists locate behind the frontal bone?.....	405
Describe the parietal bones, their position, and principal connexions,.....	406
What organs are located by the phrenologists under the parietal bones?.....	407
Describe the occipital bone, its general form and structure. Describe the form, position, and structure of its cuneiform process,.....	408
Where is the great foramen of the occipital bone, and for what is it designed?.....	409
Describe the form and position of the occipital cross,.....	410
Describe the structure and important uses of the cross,.....	411
What portions of brain fill the four depressions divided by the cross?.....	412
Describe the position of the temporal bones. Describe the squamous plate,.....	413
Where do we find the petrous portion of the temporal bone? Name some of the important passages contained in it, .	414-415
What is the structure, and what the function of that large prominence of the temporal bone felt just behind the ear?..	416
How is the temporal bone connected with the bone of the cheek? Where do you find the articulation of the lower jaw-bone?.....	417
What is said of the sphenoid bone, its position, and its cells?	418
What is said of the position and structure of the ethmoid bone?.....	419
How are the bones of the cranium connected with each other?	420
By what membranes is the cranium covered externally and internally? What is the condition of the bones of the cranium in childhood? How do certain savages flatten their heads? What has this to do with cranioscopy?.....	421
What is said of the process of ossification in the bones of the head?.....	422
What great advantages result from the imperfection of the cranial bones in childhood?.....	423-425
What changes take place in the form of the cranium from mental exercise, and from age?.....	426
Describe some of the mechanical advantages resulting from the peculiar form of the cranium,.....	427
Describe the manner of the articulation of the head with the atlas vertebra, and the motions of the joints,.....	428
What is the form and what the name of the uppermost vertebra?.....	429
What do you understand by the word <i>condyle</i> ?.....	430

- Describe the articulations of the head and atlas with the vertebra dentata,..... 431-432
- Describe the motions of these joints,..... 433-434
- What preserves the upright position of the head?..... 435
- Whence does the head derive its muscles?..... 436
- How do rheumatism and palsy sometimes affect the position of the head, and why?..... 436
- Of how many bones is the face constructed?..... 437
- Describe the extent and structure of the upper jaw,..... 438
- What is said of the passage of nerves through the upper jaw, and *tic-douloureux*?..... 440
- What is said in relation to the sympathetic connexions of the nerves of the upper jaw?..... 441
- Describe some of the peculiarities of the structure, mode of growth and functions of the teeth. Have they sensation? What is the enamel? What is meant by the term alveolar processes?..... 442-445
- What becomes of the socket when the tooth is lost?..... 446
- How are the infantile teeth thrown off? What is there in the history of horned animals resembling this?..... 447
- What proof that an infant is not designed to be carnivorous do you find in the history of the teeth?..... 448-450
- What proof is furnished by the teeth that a grown man was not designed to live entirely on vegetables?..... 450-453
- When should a child be allowed to commence eating freely of the ordinary meats, according to the language of the teeth? 451
- What is the complete number of the infantile teeth, and how are they classified?..... 449-450-451
- How many teeth replace the infant teeth, and how many teeth has a man?..... 450-452
- Why is inattention to the teeth injurious to the health? Why are errors in diet injurious to the teeth?..... 455
- What is the spine? Describe its general form,..... 457
- What is the number of the vertebræ? How are they classified? Describe the direction of curvature in the three principal portions of the spine,..... 458
- What occasions the conical form of the spine?..... 459
- Describe the general form of a cervical vertebra, and name its several parts and processes. State which of the parts so named are peculiar to the cervical, and which common to all the vertebræ except the atlas. Has the atlas any body? 460
- Describe the articulations of the vertebræ with each other. Of what substance are the intervertebral cartilages constructed?..... 461
- What is said of the effects of weight and age on these cartilages?..... 462
- In what manner are the spinal articulations strengthened by ligamentous matter? What is the spinal canal?..... 463

State some of the advantages resulting from having the spinal column composed of many bones,..... 464

Describe the different degrees of mobility possessed by each of the great portions of the spine, and why the dorsal portion is nearly immovable,..... 465

How is decay of the bodies of the vertebræ sometimes naturally cured? Does age produce such changes?..... 466

Describe some of the consequences resulting from the manner in which the nerves pass from the spinal canal,..... 467

Describe the general form, position, and articulations of the ribs. State what are their motions,..... 468

Describe the connexions, nature, and functions of their cartilages,..... 469

At what time of life are the cartilages of the ribs liable to ossification?..... 470

Describe the sternum and its position. With what bones and cartilages is it articulated? What bony connexion has the superior extremity with the trunk?.....471-472

What muscles are the chief support of the chest to prevent the ribs and sternum from sinking down by their own weight?..... 473

What part of the chest rises most in breathing? What is the kind of motion performed by the sternum? What part of the chest is most enlarged by the elevation of the ribs in breathing, and why is it so?..... 474

What consequences would you expect in relation to the muscles of the breast and neck, from confining the lower ribs by a ligature?.....475-476

State what is the agency of the muscles of the back of the spine, in favouring the process of breathing,..... 478

Why is a habitual stoop injurious to respiration, and to the nutrition of muscles and other organs?..... 479

What bones form the pelvis?.....480-481-482

Give a general description of the sacrum. Is it a part of the spine?..... 480

Of what pieces is the os coccygis originally formed? Has it any connexion with the spine?..... 481

What and where are the ossa innominata? What have they to do with the formation of the hip-joint?..... 482

Name the bones upon which the shoulder is formed,..... 484

Describe the articulations and the functions of the clavicle,.. 484

Illustrate the uses of the clavicle by a reference to animals that are deprived of it,..... 485

Where is the spine of the scapula, and where does it terminate? What bone is articulated with its extremity?..... 486

Describe the form, position, and connexions of the process of the scapula that assists in forming the shoulder-joint,.... 487

What is the extent of motion enjoyed by the arm, independently

- of the elbow? What accident is rendered more common by this extent of motion?..... 488
- Describe the form of the upper and lower extremities of the humerus,.....487-488-489
- On what bones is the forearm constructed?..... 490
- What is the general form of the ulna? Describe the manner in which it articulates with the humerus at the elbow-joint, 491
- What is the general form of the radius? Describe the manner in which it articulates with the humerus and the ulna at the elbow-joint,..... 492
- Describe the prone and supine positions of the hand, and the manner in which they are brought about by the motions of the bones of the forearm,..... 493
- How are the bones of the forearm connected with the joint of the wrist?..... 494
- How many bones are there in the wrist? How are they united? When taken collectively, what are they called? What is their arrangement at the wrist joint?..... 495
- Describe the form, position, and connexions of the metacarpal bones. What is there peculiar in the motions of the metacarpal bone of the thumb?..... 496
- Describe the number and situation of the phalangeal bones,.. 497
- What number of bones contribute to form the superior extremity? Are there any bones connected with the tendons? If so, where do you find them, and what is their function? 498
- Describe the formation of the hip-joint,..... 500
- Describe the position of the head and neck of the femur or os femoris,..... 501
- What effect has age on the head and neck of the os femoris? Mention some of the consequences,..... 502-503
- What is the character of the internal structure of these parts? 504
- Describe the general direction and the form of the lower extremity of the os femoris,..... 505
- On how many bones is the leg constructed? What are their names? To which bones of the arm do they severally correspond?..... 506
- Describe the formation of the knee-joint. Describe the form, position, and use of the patella,..... 507
- What is said of the ligaments of the knee-joint and their accidents?..... 508
- What are the motions of the ankle-joint? What are the tarsal bones? How many of them are there? What have they to do with the motions of the foot?..... 509
- With what parts of the upper extremities do the tarsal bones correspond?..... 510
- What bones of the lower extremities correspond with the metacarpal and phalangeal bones of the hand?..... 511
- What is the whole number of bones in the lower extremities? 512

- To what extent do the ligaments contribute to the preservation of the bones of the skeleton in their proper relative position?
 What other system of organs contributes to this duty? . . . 513
 State the disadvantages that would result from the elasticity of the bones, were they solid throughout the whole skeleton, 514
 State what parts of the skeleton are rendered inelastic for the prevention of these evils, 515-518
 In what manner does the spine contribute to this purpose? . . . 516
 How is the chest protected from the force of blows? 517-518

CHAPTER XI.

- State the three fundamental postulates of the argument on muscular equilibrium in chapter xi, 519-520-521
 What renders most men right-handed? Which is generally the stronger leg? 522
 What exercises are mentioned as counteracting such changes of form? 523
 How does natural left-handedness affect the figure? What conclusion do you draw from these facts? 524
 Does the weakness of any set of muscles produce effects of a character similar to those just mentioned? 525
 Describe at length the series of changes of figure resulting from a club-foot on the right side, 525-526-527
 Are these changes usually carried very far in cases of club-foot? 528
 Describe at length the changes of form and position likely to result from the attempt to sit up straight on seats without backs, 529-530-531
 Describe the manner in which these changes are modified by the usual attitude (facing the table) in reading and writing, 532-533
 How are these vices of figure from bad attitude at the desk to be prevented? 534
 What is the common cause of a habitual stoop? 535
 Give the philosophy of the effects of Minerva braces, 536
 How should a stoop be cured? Give illustrations, 537
 Describe the manner in which the eye adapts its focal distance to the distance of the object, 538-539-540
 What is the change in the eye in old age, and its cause?
 What is the most frequent cause of shortness of sight in youth, and how may *acquired short-sightedness* be cured? . . . 541
 What is the immediate cause of squinting? What may produce the *habit* of squinting? How has squinting been sometimes cured by a surgical operation? 542
 Is squinting generally a habit? What other cause often produces it? 543

What are the principal effects of squinting upon the vision, and on the organization of the eye?.....	544
What produces inequality of the focal distances of the two eyes? What is said of its relief and cure?.....	545
What is said of the arrangement and tonicity of the involuntary muscular fibres of hollow organs?.....	546
What is a sphincter?.....	549
What is the name of the sphincter of the stomach?.....	547
Describe the muscular equilibrium of action and reaction, between the body of the stomach and the pylorus during digestion,.....	547-548-549
What are the effects of the habitual over-distention of hollow organs and their sphincters, as displayed in the stomach?	550
In what respect do the effects of the over-stimulating qualities of food or drink differ from those of their excessive quantity?.....	551

CHAPTER XII.

How are the intercostal spaces occupied?.....	554
What is said of the muscles which draw the arm backwards?	555
How are the fleshy walls strengthened on the anterior part of the chest?.....	556
What occupies the space between the uppermost dorsal vertebra, the two superior ribs, and the upper end of the sternum?	557
What divides the cavity of the chest from that of the abdomen?.....	558-559-560
What is the general form and position of the diaphragm?....	561
What are the principal contents of the chest? What is the position of the heart? Which of the lungs is the larger?..	562
Explain the general arrangement of the serous membranes, and the particular arrangement of the serous membranes of the chest,.....	563-568
Into how many serous chambers is the chest divided?....	565-566
Describe the mode in which the trachea divides to reach the lungs,.....	567
What is said of the usefulness of the double serous division between the two sides of the chest?.....	568
How many cartilages contribute to form the larynx? Describe their position and mention their names,.....	569-570-571
How is elocution subjected to the laws of gymnastics?.....	571
Where is the hyoid bone found, and what are its connexions?	573
What is the use of the cords attached to the arytenoid cartilages? What are they called?.....	571
Describe the arrangement of the mucous membrane as it passes from the trachea to the mouth and pharynx. What is meant by getting a drop the wrong way?.....	572-574

What is the reason of the difficulty experienced in curing inflammations of the larynx?..... 574

Describe the form, position, and function of the epiglottis, 575-576

By what muscular arrangement are the walls of the abdomen completed where the bony walls are deficient? Describe the arrangement of these muscles,.....577-578-579

What is the name of the serous membrane of the abdomen, and in what manner does it envelope the abdominal viscera? 580

By what route do the blood-vessels and nerves find their way to the viscera?..... 581

Describe the difference between the mobility of different viscera and its cause,.....581-582-583

What peculiarity is observed in the arrangement of serous membranes about organs subjected to great distention?... 584

Are the abdominal viscera really included in the cavity of the peritoneum?..... 585

Describe the relative position of the lungs, the diaphragm, and the liver,.....586-587

Where is the gall-bladder situated?..... 588

Where is the spleen? What are its structure and function? 589

For what is the abdomen chiefly designed?..... 590

How is the stomach connected with the œsophagus? What names are given to the two extremities of the stomach?... 591

Describe the position of the stomach and its extremities,... 592

Describe the position, direction, and function of the duodenum, and its accessories,..... 593

Describe the connexions of the small intestines,..... 594

What process is carried on in the small intestines, and how is the mucous coat modified to promote it?..... 595

Describe the manner in which the small terminates in the great intestine,..... 596

What is the cœcum? What is the apendicula vermiformis? 597

Where is the cœcum situated? Describe the different portions of the colon as regards their route and connexions,... 598

Describe the character of the vena portæ and the circulation in the liver, with the origin of bile,..... 599

What connexions exist between the functions of the liver and those of the lungs?..... 600

Is the portal system of veins provided with valves?..... 601

Mention some of the ill effects of pressure on the abdomen as influencing the circulation of the blood,.....602-603-604

CHAPTER XIII.

Describe the action of the intercostal muscles, and those of the neck and back in effecting inspiration,.....605-608

Describe the agency of the diaphragm and the abdominal muscles in inhalation,..... 609

Describe the process of exhalation,.....	610
What consequences of the dependence of respiration on the condition of the muscular system are particularly mentioned?.....	611
What is said of the effects of age on the mechanism of breathing?.....	612
Describe the effects of mechanical restraint of the muscular motions of the chest and abdomen,.....	613-616
What is said of the effect of cleanliness on the health of the lungs?.....	617

CHAPTER XIV.

How is the secretion of saliva stimulated?.....	619
How are some of the ill effects of chewing tobacco accounted for?.....	620
What illustrations of the ill effects of bolting provisions at meals are given? How may milk be rendered wholesome for adults who cannot take it fresh?.....	621
What is said of the action of the stomach on food and on the general effects of debility of the abdominal muscles on digestion?.....	623
Describe the action of the stomach upon successive portions of the food,.....	623
What is said of the immediate effects of a meal on the circulation, and the necessity of rest after it?.....	624
What distinction is made between the absorption of meats and drinks?.....	625
What process is effected in the duodenum? What do you understand by the peristaltic motion of the intestines?....	626
Describe the process of vomiting, and its connexion with the discharge of bile,.....	627
What membrane is essential to the formation of a blood-vessel, and where is it found the only coat of a blood-vessel?	630
What protects this membrane in places external to the bones?	631
Why is a third coat necessary in the arteries? Describe its structure and functions,.....	632-633
Describe at length the effects of exercise on the circulation in the veins,.....	634-639

CHAPTER XV.

Is there any proof that any thing material passes along the nerves when they exercise their functions?.....	641
Tell what we know of the cause or effect of nervous action in the nerves of organic life,.....	642
What is stated in proof of the fact that every nervous fibre	

- has its own peculiar function? Prove that this function resides in all parts of the fibre,.....643-644
- Can nerves communicate impressions one to another?..... 645
- What nerves communicate with the mind? Where do the nerves of sense chiefly originate?..... 646
- Have the nerves of the five senses really any consciousness of sensation? What proof is given to the contrary?..... 647
- Describe the location, function, and general arrangement of the dura mater,..... 648
- Describe the falx and the tentorium,..... 649
- What important parts are separated by the tentorium?..... 650
- Describe the lesser falx,..... 651
- Into how many compartments is the cavity of the cranium divided by the falx and tentorium? What names are given to the portions of the brain separated by these membranous processes, 652
- Describe the membrane lying immediately below the dura mater,..... 653
- What is said of the convolutions of the brain?..... 654
- Name and describe the membrane lying beneath the arachnoid, 655
- Describe the various external divisions of the brain from the text and the accompanying figure,..... 656-657-658
- Recapitulate the general structure of the substance of the brain,..... 659
- What is said of the condition of nervous fibres within ganglia? 660
- What is said of the origin and termination of the fibres of the brain? 661
- What proof is there that the communication between the mind and the nerves does not take place in the cortical substance? What great deduction is drawn from this fact?..... 662-663
- What proof is there that consciousness and will are not functions of any part of the brain?..... 664-665
- But if consciousness and will are not functions of the whole brain or of any part of the brain, of what part of the organization are they functions?..... 666
- What is it that is conscious and wills?..... 667
- What proof is drawn from the history of disease to show that our mental operations are modified by our organization?... 668
- What is said of the seat of the mind?..... 669
- What is the real general nature of the brain viewed as compared with other nervous organs?..... 670
- Are there any distinct nerves in the brain? If so, by what name are they generally called?..... 671
- In what order are the different parts of the brain developed as we ascend from the inferior animals to man?.... 672-673-674
- In what way does the brain become developed in the advance from infancy to manhood?..... 675
- Describe at length the proofs that are given of the fact that the

- mental faculties advance with the developement of the brain,.....676-679
- What is said on the claims of phrenology?..... 680
- What parts of the nervous system occupy the spinal canal? 681
- What appearances are presented by a horizontal section of the spinal marrow?..... 682
- What is the course of the four columns of the spinal marrow? 683
- What is added to the spinal marrow in the cervical portion of the spinal canal?..... 684
- What is the real structure of the spinal marrow as compared with other parts of the nervous system?..... 685
- Describe the manner in which the columns of fibres enter the head,.....686-687
- Describe the manner in which the fibres distribute themselves after entering the brain,.....688-689
- Do the fibres of the spinal marrow and medulla oblongata form the bulk of the brain? Has the brain any feeling?..... 690
- Describe the arrangement of the medullary fibres that admits of the enlargement of the head in dropsy of the brain,.... 691
- What is stated as one of the principal errors of most phrenologists in investigating the functions of the multitude of organs forming the human brain?.....692-693
- Is phrenology a physical or a metaphysical science?..... 693
- In what class of functions should we seek for the functions of the nervous fibres of the brain?..... 694
- What are the senses?..... 695
- Give some reason for supposing that man requires other senses than those called the five senses to enable him to judge of all the physical properties of matter; and state where these organs can be found,.....696-697
- Give some reason for supposing that man requires peculiar senses to awaken his instinctive feelings, and state where we should seek their organs,..... 698
- Give some reasons why man requires peculiar senses to awaken his faculties for reasoning on cause and effect, resemblances, the order of the time of events, and other things which have nothing to do with the general physical properties of matter,.....699-700
- What think you of the opinion of phrenologists on this subject?..... 701
- What is the difference between phrenology and cranioscopy? May the principles of the one be true and the practice of the other fallacious?..... 702
- How does the surface of the head agree with the form of the skull?..... 704
- How nearly does the form of the skull agree with that of the brain?..... 705
- State how Dr Gall endeavoured to investigate the functions of the cerebral organs,..... 706

- Can the exercise of the faculties alter the form of the cranium?
 Why does not a development of the base of the brain give rise to an elevation of the top of the head?..... 707
- Is it as easy to compare the development of the brain in two individuals, as it is to determine the relative developments of different parts of the brain in one individual?..... 708
- On phrenological principles is it true that the larger the head the more powerful is the mind of the owner?..... 709

CHAPTER XVI.

- What do you understand by the term temperament?.....710-713
- Can the general balance of vital power between different parts be altered consistently with health?..... 711
- Are such alterations of balance ever rendered necessary by circumstances?..... 712
- What is meant by a natural or correct temperament?..... 713
- Is the number of temperaments limited?..... 714
- How many general temperaments are commonly acknowledged by physiologists?.....715-716
- Describe the sanguine temperament,..... 717
- What is the effect of the sanguine temperament on the mental operations?..... 718
- What are the effects of an excess of the sanguine temperament?..... 719
- What is said of undue predominance of the venous system?
 What is said of the undue predominance of the portal system?720-721
- Describe the bilious temperament,..... 722
- What is said of the mental and physical powers of endurance in the bilious temperament?..... 723
- Describe the lymphatic or phlegmatic temperament,..... 724
- What is said of the nervous temperament?.....725-726
- What is said of the peculiar temperament of women and children?..... 727
- Can a temperament be changed by treatment? Give examples,728-729
- Can the frame have one temperament and a particular organ another?..... 730
- What difficulty does this throw in the way of cranioscopy?.. 731
- What is said of the causes and nature of idiosyncrasy?..... 732

GLOSSARY

Of the terms used in this work, with derivation and accent : as well as plural and genitive forms, when necessary ; the words not yet adopted into English being printed in Italics.

- Abdo'men, *n.* Latin, from *abdere*, to cover or hide. 325.
Abdom'inal, *adj.* appertaining to the abdomen.
Acetab'ulum, *n.* Pl. *acetabulæ*. Latin, a vinegar cup. The cavity of the hip joint. 500.
Ad'ipose, *adj.* Latin, *adeps*, fat. Appertaining to fat. 71.
Anastom'osis, *n.* Pl. *anastomoses*. Greek, the formation of a mouth or opening. The junction of two vessels. 268.
Anten'na, *n.* Pl. *antennæ*. Latin, the yard of a ship. The feelers of insects, crabs, spiders, &c. 19.
Aor'ta, *n.* Greek, *αορτη*. The great artery of the nutritive system. 264.
Appendic'ula, *n.* Latin. A little appendage. 597.
Ary'tenoid, *adj.* Greek, *αρτηρη*, a ladle, and *ειδος*, form ; ladle shaped. A membrane of the brain. 571.
Au'ricle, *n. s.* Latin, *auricula*, the external ear. A receiving cavity of the heart, so called because it has an appendage resembling an ear. 262.
Bran'chia, *n.* Pl. *branchiæ*. Latin, the gill of a fish. The organs of breathing in aquatic animals. 243.
Brid'reus, *n.* Latin, a fabulous giant, with a hundred arms. A genus of the order of sea-stars. 94.
Bron'chia, *n.* Pl. *bronchiæ*. Latin, the branches of the wind-pipe. 252.
Cancell'i, *n.* Latin, *used only in the plural*, cross-bars. The meshes of a net-work of broad fibres. Imperfect cells. 391.
Can'cellated. Composed of cancelli.
Carbace'a, *adj.* Latin, from *carbasus*, a linen garment. 83.
Car'diac, *adj.* Greek ; *καρδια*, the heart. Relating to the heart. Lying towards the heart. 591.
Car'pus, *n.* Pl. *carpi*. Latin, the wrist. 495.
Car'pal, *adj.* Appertaining to the wrist.
Ca'va, *adj.* Pl. *cavæ*. Latin, feminine of *cavus*, hollow. 263.

- Cerebellum*, *n.* Pl. *cerebella*. Latin. The lesser or posterior brain. 412.
- Cerebrum*, *n.* Pl. *cerebra*. Latin. The greater or principal brain. 412.
- Cereus*, *n.* Pl. *cerei*. Latin, a waxen taper. A genus of plants. 16.
- Chæra*, *n.* Pl. *chæræ*. Latin, the name of an unknown plant. The name of a modern genus of aquatic plants. 87.
- Chyle*, *n.* Greek, *χυλος*; juice. The nutritive fluid in the frame of animals. 194.
- Chyme*, *n.* Greek, *χυμος*; juice. The nutritive portions of food, when prepared to enter the frame of animals. 194.
- Cilium*, *n.* Pl. *cilia*, an eye-lash. 82.
- Ciliary*, *adj.* Appertaining to, or armed with cilia.
- Cineritious*, *adj.* Latin, *cineritius*, ash-coloured, or like to ashes. 283.
- Cæcum*, *n.* Pl. *cæca*. Latin, a deep cavity. 597.
- Com'missure*, *n.* Latin, *commissura*, a knot, or joint. A band of fibres, or a firm joint connecting two similar organs together; as the two sides of the brain, or two bones of the cranium. 671.
- Con'dyle*, *n.* Greek, *κονδυλος*, a knuckle. A prominent portion of bone, forming part of a moveable joint. 430.
- Cor'tical*, *adj.* Latin, *cortex*, bark. Appertaining to or forming the rind or bark. 284.
- Coc'cyx*, *n.* Genitive *coccygis*. Pl. *coccyges*. Latin; a cookoo. A bone resembling a cookoo's beak. 481.
- Cranios'copy*, *n.* Greek, *κρανιον*, the skull, and *σκοπεω*, to view. The art of examining into the form of the brain by viewing the head. 402.
- Crib'riform*, *adj.* Latin, from *cribrum*, a sieve. 419.
- Cri'coid*, *adj.* Greek, from *κρικος*, a ring, and *ειδος*, form. Ring-shaped. 570.
- Crustac'ea*, *n.* Latin, from *crusta*, a crust. A class of animals covered with a crust or shell like that of the crab. 155.
- Cu'neiform*, *adj.* Latin, from *cuneus*, a wedge. Wedge-shaped. 408.
- Cu'tis*, *n.* Latin, the skin. The true or living skin, as distinguished from the cuticle or scarf skin. 353.
- Cyath'ena*, *n.* Greek, *κυαθειον*, a little cup. The name of a species of animalcule, formed like a little cup. 84.
- Degluti'tion*, *n.* Latin, *deglutio*, the act of swallowing. 227.
- Denta'ta*, *adj.* Latin, toothed. Tooth-like. 431.
- Di'aphragm*, *n.* Greek, *διαφραγμα*, a partition. The muscle that divides the abdomen from the thorax. 560.
- Duode'num*, *n.* Latin, from *duodeni*, (counted) by twelves. The first twelve fingers-breadth of the small intestine. 593.
- Du'ra*, *adj.* Latin, hard. 648.
- Echi'noder'mata*, *n.* Greek, from *ηχινος*, a hedge-hog, a sea-urchin, and *δερμα*, a hide. A class of cold-blooded marine animals, with a tough skin, generally armed with prickles. 152.
- En'siform*, *adj.* Latin, *ensiformis*, sword-shaped. 471.

- Epiglot'tis*, *n.* Greek, from *επι*, upon, and *γλωττις*, the mouth-piece of a flute, or the opening of the wind-pipe. 575.
- Epithe'lium*, *n.* Greek, from *επι*, upon, and *θηλω*, to bloom. The cuticle covering the red part of the lip, the mouth and œsophagus. 366.
- Eth'moid, *adj.* Greek, from *ηθμος*, a seive, and *ειδος*, form. A bone of the skull and nose, so named from its cribriform plate. 419.
- Falx*, *n.* Genitive *fulcis*; pl. *falces*. Latin, a sickle. A sickle-shaped portion of a membrane of the brain. 649, 652.
- Fasc'ia*, *n.* Pl. *fasciæ*. Latin, a band or girdle. 138.
- Fem'oral, *adj.* Appertaining or relating to the thigh, or thigh-bone.
- Femur*, *n.* Genitive *femoris*; pl. *femora*. Latin, the thigh; the bone of the thigh, or *os femoris*.
- Fib'ula*, *n.* Pl. *fibulæ*. Latin, a brace or cramp. The smaller bone of the leg. 506.
- Flus'tra*, *n.* Latin, a calm of the sea. A genus of polypi, which build their cells chiefly in quiet water. 83.
- Fora'men*, *n.* Pl. *foramena*. Latin, an aperture. 409.
- Front'al, *adj.* Latin, from *frons*, the forehead. Appertaining to the forehead. 401.
- Gan'glion*, *n.* Pl. *ganglia*. Latin; from Greek *γαγγλιον*, a tumour upon a tendon or nerve. Now, a nervous organ, in which the fibres of various nerves are intermingled. 287.
- Gem'mule, *n.* Latin, *gemmulus*, or little gem. The living bud separated from sponges and some polypi, which multiply the race. 88.
- Glot'tis, *n.* Genitive, *glottidis*. Latin; from the Greek *γλωττις*, the mouth-piece of a flute. The opening of the wind-pipe. 571.
- Gorgo'nia*, *n.* Pl. *gorgoneæ*. Latin, a tribe of corallines, branching like shrubbery, named from the fabulous *Gorgons*, whose heads were armed with snaky locks. 93.
- Gy'rans*, *part.* Latin, *gyrare*, to whorl. Whorling round. The specific name of a plant. 105.
- Hedysa'rum*, *n.* Greek *ηδυσαρον*, a genus of pod-bearing plants; from *ηδης*, sweet or pleasant. 105.
- Hepat'ic, *adj.* Latin, *hepaticus*, from *hepar*, the liver,—appertaining to the liver. 599.
- Hisp'idus*, *adj.* Feminine, *hispida*, neuter *hispidum*. Latin, hairy; thorny; prickly. 599.
- Hu'merus*, *n. s.* Genitive, *humeri*. Latin, the shoulder; the bone of the arm. 487.
- Hy'drogen, *n.* Greek, *υδωρ*, water, and *γενναω*, to produce. A gas, which, in burning, produces water. 230.
- Hy'oid, *adj.* Greek, *υειδες*, from the letter *υ*, and *ειδος*, form. Shaped like an ypsilon. Applied to the bone which supports the base of the tongue. 573.
- Idiosyn'cracy, *n.* Greek, *ιδιος*, proper, *συν*, together with, and *κρασις*, the temper of the blood or humours. Mixed with the

- proper conformation of the blood. An individual peculiarity in the constitutional balance of the vital structure which produces health. 732.
- Ima'go, *n.* Latin; an image or picture. The perfect state of insects; especially of the butterfly and moth. 99, 100.
- Imbibition, *n.* Latin, from *in*, and *bibere*, to drink. The act of sucking in. 192.
- Innomina'tus, *adj.* Feminine, *innominata*, neuter, *innominatum*. Latin; unnamed; of little celebrity. 482.
- Intercos'tal, *adj.* Latin, from *inter*, between, and *costa*, a rib. Placed between the ribs. 304.
- Lac'teal, *n.* Latin; *Lac*, genitive *lactis*, milk. A vessel conveying chyle; *adj.*, appertaining to chyle (from the milky colour of chyle). 195.
- Lar'va, *n.* Pl. *larvæ*. Latin; a mask. An insect in its first form after leaving the egg; as, a caterpillar. 99, 100.
- La'rynx, *n.* Greek, *λαρυγξ*; the upper portion of the wind-pipe, in the throat. 569.
- Lympha'tic, *n.* Latin, *lymphæ*, watery humour. A vessel conveying towards the heart, the lymph,—a watery fluid; *adj.*, appertaining to the lymphatics.
- Mad'repore, *n.* Latin, *mador*, moisture, and *pora*, a loose calcareous stone. A genus of corals. 94.
- Ma'ter, *n.* Latin; mother. 648.
- Medu'sa, *n.* Pl. *medusæ*. Latin; one of the fabulous Gorgons, whose hair was turned to snakes, by Minerva. A genus of gelatinous marine animals, with long stinging tentaculæ, called sea-nettles. 52.
- Medul'la, *n.* Latin; the marrow. This term is also applied to the nervous matter contained in the spinal canal. 646.
- Megalis'ta, *adj.* Greek, from *μεγας*, powerful, great. 105.
- Metacar'pus, *n.* Greek, *μετα*, next to, and *καρπιων*, the wrist. The five bones forming the palm of the hand. 496.
- Metatar'sus, *n.* Greek, *μετα*, next to, and *ταρσος*, the heel. The five bones forming the chief part of the instep. 511.
- Mollus'cus, *n.* Pl. *mollusca*. Latin, a nut with a thin shell. A class of soft-bodied animals resembling and including those of shell-fish. 152.
- Muco'sus, *adj.* Feminine, *mucosa*, neuter, *mucosum*. Latin, mucous. 350.
- Mus'cipula, *n.* Latin, from *musca*, a fly, and *capere*, to catch. A fly-trap. 16.
- Neural'gia, *n.* Greek, *νευρον*, a nerve or tendon; and *γαλος*, pain. Pain of a nerve. 614.
- Neurele'ma, *n.* Greek, *νευρον*, a nerve or tendon, and *λεμμα*, that which is peeled off. The membrane investing a nerve. 289.
- Ni'trogen, *n.* Greek, *νιτρον*, any salt used in washing, and *γεννω*, to produce. A gas obtained from nitre or salt-petre, a salt which was formerly used in washing. 50.

- Oblongatus*, *adj.* Feminine, *oblongata*; neuter, *oblongatum*. Latin, oblong. 646.
- Occipital*, *adj.* Latin, *oc'ciput*; genitive, *occipitalis*; the back part of the head. Belonging to the back part of the head. 408.
- Oeso'phagus*, *n.* Greek, *αισος*, wicker or basket work, and *φαγω*, to eat. The canal leading from the throat to the stomach; the gullet. 368.
- Os*, *n. s.* Pl. *ossa*. Latin; a bone. 482.
- Os'seous*, *adj.* Bony; relating to, or composed of bone. 157.
- Ossif'ic*, *adj.* Latin, *os*, a bone, and *facere*, to make. Creating or depositing bone.
- Ossifica'tion*, *n.* The act of forming or depositing bone; a conversion of other living structures into bone.
- Os'sify*, *v.* To change into bone; to form bone.
- Ox'ygen*, *n.* Greek, *οξυς*, an acid, and *γενναω*, to produce. A gas composing part of air and water, which, uniting with other substances, produces many of the acids. 230.
- Pan'creas*, *n.* Greek, *παν*, all, and *κρεας*, flesh. A secretory gland near the stomach, supplying the duodenum with a fluid resembling saliva. 227, 327.
- Pancreat'ic*, *adj.* Belonging to, or coming from the pancreas.
- Pan'nicle*, *n.* Latin, *panniculus*, diminutive of *pannus*, a garment. 358.
- Papil'la*, *n.* Pl. *papillæ*. Latin; a nipple. 350.
- Pap'illary*, *adj.* Composed of, or belonging to papillæ.
- Patel'la*, *n.* Pl. *patellæ*. Latin; a pan. The bone forming the cap of the knee. 507.
- Parie's*, *n.* Pl. *parietes*. Latin; a wall. The sides of a cavity.
- Parie'tal*, *adj.* Latin, from *paries*, a wall (or side of a building). 406.
- Pel'vis*, *n.* Pl. *pelves*. Latin; a basin. The part of the skeleton which gives attachment to the bones of the lower extremities. 325.
- Perichon'drium*, *n.* Greek, *περι*, around, and *χονδρος*, a cartilage. The membrane investing a cartilage. 176.
- Pericra'nium*, *n.* Pl. *pericrania*. Greek, *περι*, around, and *κρανιον*, the skull. The external periosteum of the skull, exclusive of the face. 176.
- Perios'teum*, *n.* Greek, *περι*, around, and *οστεον*, bone. The membrane enveloping bone. 175.
- Peristalt'ic*, *adj.* Greek, from *περι*, upon, and *σπρωλλω*, to contract or press. Applied to the vermicular motion by which food is urged along the alimentary canal. 697.
- Peritone'um*, *n.* Greek, *περιτοναιον*, the membrane stretched over the contents of the abdomen. 580.
- Petal*, *n.* Latin, *petalum*. The botanical name for the flower-leaves of plants. 16.
- Pet'rous*, *adj.* Latin, from *petra*, a stone. Very hard; stony. 414.
- Phal'anx*, *n.* Pl. *phalanges*. Latin; a troop or body of soldiers drawn up in close order. A term applied to each range of bones between corresponding joints of the several fingers or toes. 497.

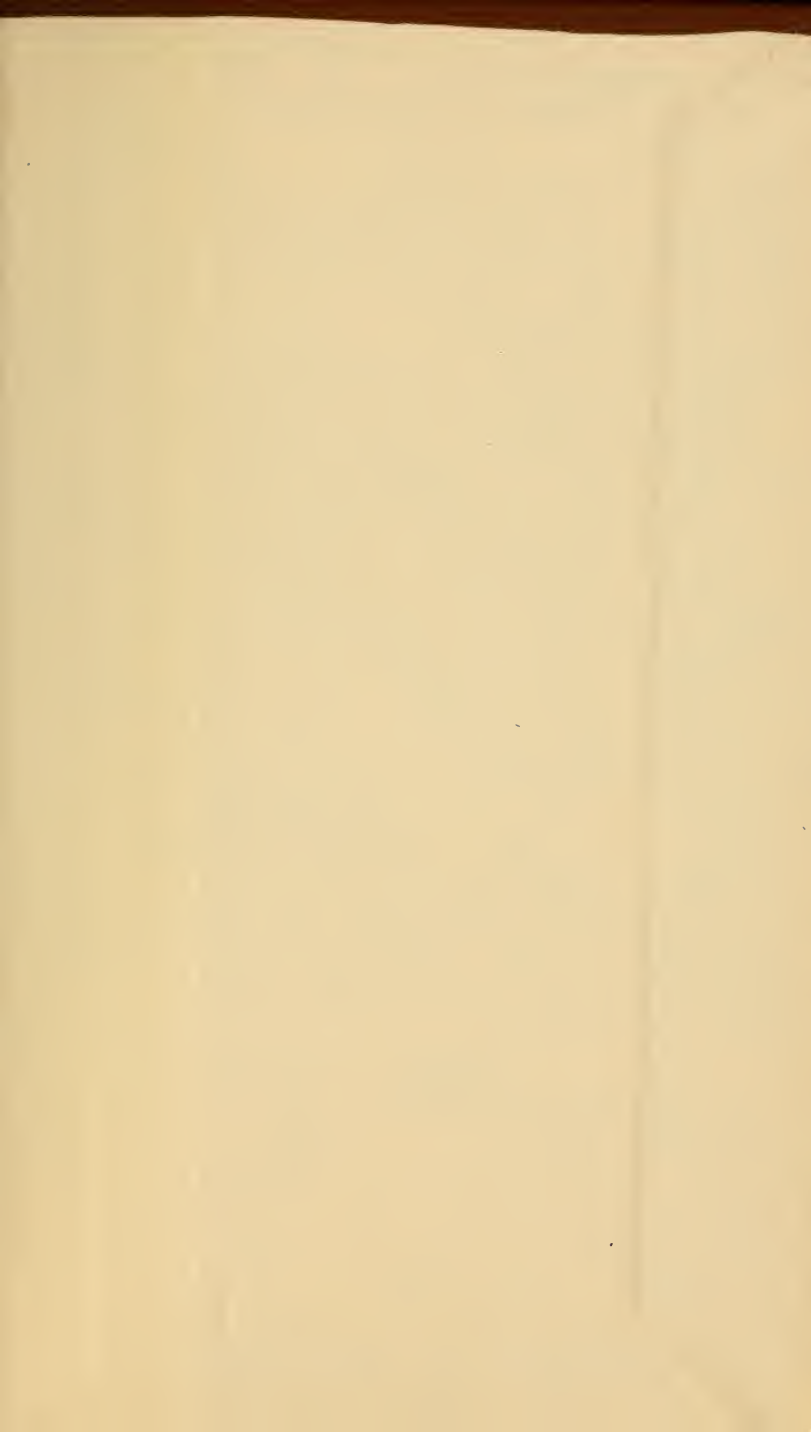
- Phalange'al, *adj.* Appertaining to the phalanges.
- Pha'rynx, *n.* Greek, φαρυγξ, the upper part of the gullet. 368.
- Phe'nomenon, *n.* Pl. *phenomena*. Latin, from the Greek, φαινόμενον, an appearance in nature. 10.
- Physa'lia, *n.* Greek, φυσάλις, a bubble. A genus of gelatinous animals which float like bubbles on the ocean. 105.
- Pi'a, *n.* Latin; fem. of *pious*, tender, delicate. 655.
- Pleu'ra, *n.* Pl. *pleuræ*. Greek, πλευρα, the side; the rib. The membrane which is stretched over a lung, and which lines the corresponding side of the thorax. 565.
- Plex'us, *n.* Latin; a piece of plating. A net-work of nerves. 293.
- Pol'ypus, *n.* Greek, πολυπους, many-footed. A class of marine animals with many tentaculæ, which construct the corals and coral-lines. The term was formerly given to the cuttle-fish, and is now vulgarly applied to the Hydræ, which are fresh-water animals. 81.
- Por'ta, *n.* Genitive, sin. *portæ*, gen. pl. *portarum*. Latin; a gate. Thus: *vena portæ*, the vein of the gate; more frequently, *vena portarum*, the vein of the gates: from the chief cleft or entrance into the liver, called the gate or gates of the liver. 599.
- Pu'pa, *n.* Pl. *pupæ*. Latin; a doll. An insect in the inactive state, during which it is changed from a larva to an imago. 99, 100.
- Pyl'o'rus, *n.* Greek, πύλωρος, a watchman at the gate; a janitor. The lower end of the stomach, where circular muscular fibres stand guard against the passage of undigested matter. 547.
- Ra'dius, *n.* Pl. *radii*. Latin; the spoke of a wheel. A line drawn from any central point within a curve, or curved solid, to the circumference or periphery. 492.
- Rec'tum, *n.* Pl. *recta*. Latin; from *rectus*, straight. The straight intestine. 598.
- Re'te, *n. s.* Latin; a net. A net-work. 350.
- Retic'ular, *adj.* Latin; from *rete*, a net. Netted; forming meshes. 391.
- Sa'crum, *n.* Latin; the bone of the pelvis which forms the next to the last portion of the spinal column, called the coccyx. 480.
- Scap'ula, *n.* Pl. *scapulæ*. Latin; the shoulder-blade. 484.
- Seba'ceous, *adj.* Latin; *sebaceus*, producing or relating to tallow. 341.
- Secre'tory, *adj.* Latin, from *secretus*, put aside. Performing the office of separating matter from the circulating fluid. 223.
- Sertula'ria, *n.* Latin; a diminutive of *sertum*, a wreath. A genus of polypi. 91.
- Sig'noid, *adj.* Greek; from the name of the letter σ, sigma, and εἶδος, form. Shaped like the letter s. 598.
- Sphe'noid, *adj.* Greek, σφηνοειδές, wedge-shaped. 418.
- Sphincter, *n. s.* Latin; a bundle of muscular fibres, closing an orifice by their contraction; thus; *sphincter palpebrarum* is an anatomical name of the muscle which closes the eyelids. 549.
- Squa'mous, *adj.* Latin, *squameus*, scaly. 413.

- Ster'num*, *n.* Latin; the breast-bone. 468.
- Tarsus*, *n.* Pl. *tarsi*. Latin; the heel. The back part of the foot. The seven bones of the foot placed behind the instep. 509.
- Tentac'ulum*, *n.* Pl. *tentacula*. Latin; a little feeler. 81, 106.
- Tentor'ium*, *n.* Latin; a tent. 649.
- Testa'cea*, *n.* Latin; from *testaceus*, covered with a shell. The class of shell-fish. 152.
- Tib'ia*, *n.* Pl. *tibiæ*. Latin; the shin-bone. 506.
- Tho'rax*, *n.* Latin; the chest. 197, 324.
- Thora'cic*. Belonging to the chest.
- Trach'ea*, *n.* Pl. *tracheæ*. Greek, *τραχεα*, the wind-pipe. 251. Also applied to the air-passages in insects. 241.
- Transpira'tion*, *n.* Latin, *trans*, beyond, and *spirare*, to breathe. An exhalation through any membrane.
- Tubipor'a*, *n.* Pl. *tubiporæ*. Latin, *tubus*, a tube, and *porus*, a calcareous stone. A genus of polypi. 92.
- Ul'na*. *n.* Latin; the elbow; the fore-arm. The bone of the fore-arm which forms the principal part of the elbow-joint. 491.
- Ve'na*, *n.* Pl. *venæ*. A vein. 591.
- Ve'ra*, *adj.* Latin; feminine of *verus*, true. 353.
- Ver'mifor'mis*, *adj.* Latin, *vermis*, a worm, and *forma*, form. Having the form of a worm. 597.
- Ver'tebra*, *n.* Pl. *vertebræ*. Latin; a joint. A bone of the spine. 457.
- Vis'cus* *n.* Pl. *viscera*. Latin; an internal organ; as the brain, stomach, heart, &c. 580.
- Vorticel'la*, *n.* Pl. *vorticellæ*. Latin; diminutive of vortex; a whirling body. A genus of animalcules.

THE END.







LIBRARY OF CONGRESS



0 005 526 994 4

